STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

Number 26 March 2001

Au Sable River Assessment

Troy G. Zorn
and
Steven P. Sendek

www.dnr.state.mi.us

FISHERIES DIVISION
SPECIAL REPORT

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Special Report 26
March 2001

Au Sable River Assessment

Troy G. Zorn
and
Steven P. Sendek

Cover photo: dated July 9, 1910, depicts rapids on the Au Sable River approximately one quarter mile downstream of the site of present day Cooke Dam. The rapids are presently impounded by Foote Pond. These and numerous other high-gradient rapids on the lower 100 miles of Au Sable River are presently impounded by six Consumers Energy ponds.

Michigan DNR
Printed under authority of Michigan Department of Natural Resources
Total number of copies printed 475 — Total cost $3,530.47 — Cost per copy $7.43

Suggested Citation Format

Zorn, T. G., and S. P. Sendek. 2001. Au Sable River Assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 26, Ann Arbor, Michigan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

(published in a separate volume)

ACKNOWLEDGMENTS

We thank the many individuals who contributed to this report. We especially appreciate the following individuals providing their input and data for the different sections of this report: Barbara Mead- Michigan Department of State, Bureau of History; Brian Benjamin- Huron Pines RC&D; Rick Henderson- MDEQ, Geological Survey Division; Paul Wessel- MDEQ, Land and Water Management Division; David Battige- Consumers Energy; Bill Taft, Amy Peterson, Steve Holden, Gary Kohlepp, Chris Hull, Bob Day, and Rick Shoemaker- MDEQ, Surface Water Quality Division; Lynn Scrimger, Jerry Weinrich, and Tom Weise- MDNR, Wildlife Division; Dr. Gerald Smith- University of Michigan; Tracy Filippi- United States Forest Service; Gary Whelan, Kyle Kruger, Carl Latta (retired), Jim Schneider, Rick Clark, and Paul Seelbach- MDNR Fisheries Division. We are grateful to previous river assessment authors (especially Rich O'Neal) whose documents helped serve as guides for this one. Thanks goes to reviewers Jan Fenske, Liz Hay-Chmielewski, Kyle Kruger, Andy Nuhfer, and Paul Seelbach for helpful comments on a previous draft of this document and their input along the way. A big thanks, as always, to Al Sutton and his trusty computer skills for producing the maps and many of the figures in this report.

EXECUTIVE SUMMARY

This is one in a series of river assessments being prepared by the Michigan Department of Natural Resources Fisheries Division for Michigan rivers. This report describes the physical and biological characteristics of the Au Sable River, discusses how human activities have influenced the river, and serves as an information base for managing the river's future.

River assessments are intended to provide a comprehensive reference for citizens and agency personnel who need information about a river. By pulling together and synthesizing existing information, river assessments show the intertwined relations between rivers, watershed landscapes, biological communities, and humans. This assessment shows the influence of humans on the Au Sable River, and is intended to increase public concern for the river. We hope it will encourage citizens to become more actively involved in decision-making processes that provide sustainable benefits to the river and its users. To help achieve this, assessments identify problem areas within a river system and identify potential opportunities for alleviating them. Assessments also identify the types of information needed to better understand, manage, and protect the river.

This document consists of four parts: an introduction, a river assessment, management options, and public comments (with our responses). The river assessment is the nucleus of each report. It provides a description of the Au Sable River and its watershed in twelve sections: geography, history, geology and hydrology, soils and land use patterns, channel morphology, dams and barriers, water quality, special jurisdictions, biological communities, fishery management, recreational use, and citizen involvement.

The management options section of the report identifies a variety of actions that could be taken to protect, restore, rehabilitate, or better understand the Au Sable River. These management options are categorized and follow the main sections of the river assessment. They are intended to provide a foundation for public discussion, setting priorities, and planning the future of the Au Sable River.

The Au Sable River drains 1,932 square miles of northeastern Lower Michigan into Lake Huron. Its basin contains portions of eight counties: Otsego, Crawford, Montmorency, Roscommon, Ogemaw, Oscoda, Alcona, and Iosco. For the purposes of discussion, the mainstem Au Sable River is divided into six sections or segments, each reflecting how the river changes as it flows across different landforms, receives tributaries, and passes through lakes and ponds. Progressing downstream from the river's headwaters, these segments are: Headwaters to Wakeley Bridge; Wakeley Bridge to Mio Pond; Mio Pond to McKinley Bridge; McKinley Bridge to Five Channels Dam; Five Channels Dam to Foote Dam; and Foote Dam to Lake Huron. Major tributaries of the Au Sable River include the North, South, and East branches Au Sable River, Big Creek-South, and the Pine River.

The Au Sable River has played many roles in the history of northeast Michigan. Native Americans used the river as a transportation route and its fishes for food. Early Europeans used the river for commercial lumbering, fishing, and trapping. Railroad access and the discovery of Arctic grayling resulted in development of major recreational fisheries on the Au Sable River in the late 1800s. In the early 1900s, the lower reaches of the river were harnessed to provide hydroelectric power. The Au Sable River continues to serve as one of Michigan's premier recreational assets.

The Au Sable River drains extensive deposits of coarse-textured sands and gravels. This unique geology causes the river to receive exceedingly high inflows of groundwater and have an exceptionally stable flow regime. The Au Sable River has probably the most stable streamflow regime of any large stream in the United States. However, hydroelectric peaking operations at dams on the lower mainstem (Au Sable River from Mio Pond to Lake Huron) caused substantial daily flow fluctuations on the river until 1994, when new operating licenses went into effect. Two exceptions to this are Mio and Foote projects, whose flows have more closely mimicked run-of-river conditions since 1966 (Mio) and 1989 (Foote). Variable flows generally provide poor conditions for fish reproduction and survival. Flows are presently more stable, but are still affected by dams and improperly operated lake-level control structures.

Coarse-textured glacial deposits, in combination with the basin's relatively steep topography, result in extremely high inflows of groundwater to the Au Sable River. Groundwater dominated flows are key to cold water conditions needed by trout and salmon. Large pulses of groundwater appear to enter the river in discreet areas where steep topography and coarse-textured glacial deposits co-occur. Such areas are in portions of the upper mainstem (the mainstem Au Sable River upstream of Mio), several of its major tributaries, and on the lower mainstem. Dams on the lower mainstem offset the cooling effect of groundwater inflows, and substantially reduce populations of coldwater fishes.

Soils in the watershed are predominantly sands, poorly consolidated, and often quite vulnerable to erosion. Past logging activities, improperly designed road-stream crossings, unmaintained access sites, and other poor land use practices released considerable sand sediment into the Au Sable River. Sand smothers gravel and cobble habitats critical for reproduction and survival of many fish and invertebrate species, and fills in pools that are used by larger fish. Erosion sites along the mainstem and major tributaries have been inventoried and treated resulting in considerable declines in sediment delivery to the river. Ten sediment traps are periodically excavated to remove sediment currently in transport. Inventories are needed to characterize conditions at road-stream crossings and prioritize sites for treatment. Education, vigilance, and funding are needed keep erosion rates at more natural levels, and to minimize sedimentation due to human activity in the riparian corridor.

Over 80% of the Au Sable River's watershed is forested. The vegetative landscape however, has changed considerably. Much of the basin's conifer-dominated forest has been replaced by deciduous forest, and only a few remnants exist of the once extensive prairie-savannah habitat type. In many areas, riparian forests have been cleared for residential development. Riparian forests provide many benefits such as stabilizing stream banks, shading stream channels, controlling surface runoff, and providing large woody debris to the stream channel as habitat for aquatic organisms. Lowland conifer forest habitat along the lower mainstem is presently inundated by impoundments.

Residential development and growth within the watershed are proceeding at a rapid pace. Local units of government in areas characterized as very rural are dealing with residential development projects unprecedented in size for their area. Some residential development is occurring on glacial outwash deposits that are highly prone to fire. Several townships within the Au Sable River basin are presently not zoned or only have zoning at the county level. Planning is needed ensure that development occurs in a way that provides sustainable benefits to local communities and does not unduly harm the river.

The average gradient of the Au Sable River is 3.9 ft/mi (feet per mile), one of the highest of similar-sized streams in Michigan's Lower Peninsula. This gradient is not uniformly distributed throughout the river, but varies with the landforms over which the river flows. Gradient averages 4.2 ft/mi on the upper mainstem, 3.8 ft/mi on the lower mainstem, 4.9 ft/mi on the East Branch Au Sable River, 2.6 ft/mi on the South Branch Au Sable River, and 7.1 ft/mi on the North Branch Au Sable River. Diversity and productivity of fishes and other aquatic life generally increase with stream gradient, and highest values typically are where gradients are very high (10-70 ft/mi). The Au Sable River is unique among large Lower Michigan rivers because it has several miles of very high-gradient habitat and more than 16 miles of high-gradient (5-9.9 ft/mi) habitat in its lower reaches. Unfortunately, all of the very high-gradient habitat and about half the high-gradient habitat is now impounded. Dams and their ponds have eliminated most of the best rapids on this portion of the river and prevent fish from migrating between Lake Huron and nearly the entire Au Sable River.

Historically, the Au Sable River's channel was complex, with a variety of depths, velocities, and substrates, and abundant cover provided by large trees and logjams in the river. The channel of the river has been altered by human activities. Historic log-driving activities widened the channel in areas, most notably in middle portions of the North Branch Au Sable River. Increased sedimentation filled in pool habitats and smothered gravel and cobble substrates needed by many aquatic species. Past logging and residential development eliminated the old growth forest along the riparian corridor, leaving a relatively young forest and fewer large, old trees falling into the river. Past stream clearing activities and operations at hydroelectric facilities removed many large trees from the river and prevented their natural downstream transport. Addition of large trees would help rehabilitate the channel complexity in the near term, but protection of riparian forests is needed to eventually bring the channel closer to its former condition.

One hundred and nine dams are presently in the Au Sable River watershed. More than 90% of these dams are on small, tributary streams and are small in size. Except for the six hydropower dams, effects of dams in the watershed have not been quantitatively evaluated. By changing flowing water habitats to impounded habitats, dams affect rivers by: altering their natural flow regime to varying degrees; modifying temperature and water quality conditions; changing aquatic conditions to favor lake species over river species; fragmenting the river for fishes and aquatic organisms; and disrupting natural transport of sediment and woody debris. In addition, dams at lake outlets (lake-level control structures) often: disrupt natural variations in lake levels needed to maintain shoreline wetlands; eliminate aquatic species associated with natural lake outlets; prevent movement of fishes between lake and river habitats; and if improperly managed, produce detrimental flow conditions downstream.

Six of the seven dams on the mainstem Au Sable River are large hydroelectric dams on the lower mainstem. These six dams dramatically change the character of the Au Sable River. They impound roughly 38% of the mainstem. They turn extremely rare, cold water, large-river, high-gradient habitats into marginally-productive, cool ponds. They warm riverine reaches downstream of dams, making them less suitable for highly-prized coldwater fishes, such as trout and salmon. They block natural downstream transport of sediment and large woody debris, and prevent formation of river delta wetlands. Fish are entrained or killed in hydropower turbines. Estimates for 1991 showed these six hydropower projects entraining over one million fish and killing over 230,000 fish. They block migrations of fishes between Lake Huron and 93% of the Au Sable River. They prevent access to spawning rapids needed by many, large-bodied Great Lakes fishes. Populations of some species are reduced such that they need special protection (e.g. state-threatened lake sturgeon and state-endangered channel and river darters) or must be stocked. They prevent development of valuable fisheries for potamodromous fishes. Operating licenses issued to Consumers Energy in 1994 provide mitigation for some of the effects of hydroelectric projects on the Au Sable River. Dam removal, fish passage structures, and cold water discharges at Mio and Alcona dams would help alleviate some negative effects of these projects.

Eighty-two percent of the river system consists of designated trout streams (which provide water quality conditions adequate for trout survival), so keeping waters cold and well oxygenated is of paramount importance. Dams can adversely affect stream temperature and oxygen levels. Excessive temperature elevation of cold water reaches of the mainstem happens at Grayling Dam and the six hydroelectric dams. In addition, dissolved oxygen levels fell below required minimums on several occasions at the six hydroelectric dams. Continued monitoring is needed to document, and seek mitigation for, the effects of these dams. Surveys are needed to determine effects of other dams in the watershed.

Water quality in the Au Sable River is generally good, owing primarily to the limited amount of development within the basin. Nutrient levels appear to be lower than they were in the past. Relatively few point source discharges go into the river and compliance with permit requirements is good. Nonpoint source sedimentation remains an issue along portions of the river. Aside from the statewide fish consumption advisory due to mercury, no fish consumption advisories exist for fishes upstream of Foote Dam. Advisories due to high PCB levels exist for several fishes in Lake Huron and Van Etten Lake, on the lower Pine River. PCB levels in Lake Huron fishes have declined since the late 1970s and are now at relatively stable and lower levels. Levels of PCBs in Lake Huron fishes are lower than those in Lake Michigan and Lake Ontario fishes. Fish consumption advisories due to chlordane and dioxins occur for lake trout in Lake Huron.

Jurisdiction over the river happens at several governmental levels. Many federal and state statutes are associated with protection of the Au Sable River watershed. Federal Wild and Scenic River and State Natural River designations occur over 337 miles of the river system. Portions of the river are classified by the State of Michigan as Blue Ribbon Trout Streams. The Federal Energy Regulatory Commission regulates the six hydroelectric projects on the lower mainstem. Sixty-seven percent of the watershed is owned and managed by the State of Michigan (36%), U.S. Forest Service (30%), and Consumers Energy (1%). Sport fishing regulations, fish consumption advisories for the Au Sable River, and legal “navigability” of the portions of the river are determined by various entities of state government. Local units of government influence the river through special ordinances and restrictions, road commission activities, and maintenance of legal lake levels.

There is little information upon which to base characterizations of the Au Sable River’s original fish community. Most notable in the historic record of Au Sable River fishes were grayling, walleye, round whitefish, lake sturgeon, and suckers in the upper mainstem. Historic fisheries occurred in Lake Huron near the river mouth for lake whitefish, lake trout, lake herring, walleye, and yellow perch. Native Americans fished for whitefishes and lake sturgeon along the lower river.

The most dramatic changes to the river happened in the first several decades after European settlement. Arctic grayling were heavily exploited shortly after their discovery, and had disappeared from parts of the mainstem in the 1880s. Brook and brown trout were stocked during this time, and migratory rainbow trout (steelhead) were ascending the river around turn of the 20th century. Logging destabilized the river’s flow patterns, tore up stream banks, and caused tremendous sedimentation. Hydropower development fragmented the river system, eliminating migrations of fish from Lake Huron and throughout the lower mainstem. High-gradient, cold water rapids were replaced with marginally productive, cool ponds and reaches between dams were warmed. Low-head dams and lake-level control structures further fragmented the river system and altered river conditions.

Comprehensive surveys show 94 species of fishes presently or recently occurring in the Au Sable River drainage. Of these, 77 are native and presently exist within the drainage, 1 (Arctic grayling) is native but extirpated, 2 are native but their current status is unknown, 9 were intentionally introduced (8 presently exist and the current status of one is unknown), and 5 colonized the drainage via canals or dispersal from previous introductions and presently exist.

Little current information is available for characterizing present fish communities in the Au Sable River. The mainstem, East Branch, North Branch, and South Branch Au Sable rivers, Big Creek-North, and Big Creek-South drain lakes and wetlands, and in their upper reaches, and are mostly warm- to cool-water streams, too warm or marginally warm for trout. These streams accrue groundwater in their downstream reaches, becoming cold water streams. Population estimates of brown and brook trout in several reaches of the upper mainstem, North Branch, and South Branch Au Sable rivers have been conducted nearly every year since 1957. These data demonstrate the variability of trout populations over time, with variations being attributable to a variety of possible causes including habitat and water quality changes, hydrologic changes, and changes in angling pressure, regulations, and methods.

Coldwater fishes (such as trouts, whitefishes, and sculpins) compose the bulk of the catch upstream of Mio Pond. Mio and Alcona Ponds warm the river such that free-flowing reaches downstream are more suitable for coolwater fishes. The river flows through the six ponds on the lower mainstem quickly enough that the ponds are unlike natural lakes, and more closely resemble large, cool pools in the river. As a result, fish communities of the ponds are dominated by fishes (such as bowfin, northern pike, and white sucker) more typical of cool, sluggish rivers than warm lakes. The river below Foote Dam has a variety of fishes and receives migratory runs of several Lake Huron fishes.

The three fishes of special concern in the Au Sable River (lake sturgeon, channel darter, and river darter) are all associated with reaches of the river that have cool summer temperatures, are large-sized, and free-flowing. This habitat is almost entirely impounded by the four lowermost dams on the river. Lake sturgeon (threatened) are occasionally seen below Foote Dam, and remnant populations of channel darter (endangered) are now restricted to the few patches of riverine habitat that still exist. The river darter (endangered) has not been collected from the river since 1925.

Little current information is available for characterizing invertebrate communities in the Au Sable River. However, comprehensive surveys from the early 1970s showed aquatic insect communities in the upper mainstem and its tributaries to be healthy, with species diversity generally increasing downstream in response to cooler water temperatures. Surveys from the 1970s and 1990s show the degrading effects of impoundments on aquatic insect communities of the lower mainstem. Riverine reaches below dams had lower insect densities, fewer species, and fewer "sensitive" (mayfly, stonefly, and caddisfly) taxa than undammed reaches just above the ponds.

A variety of amphibians, reptiles, birds, mammals, and plants occur within the watershed, a number of which are threatened or endangered, largely due to habitat loss. Aquatic pest species in the watershed include purple loosestrife, sea lamprey, whirling disease, zebra mussels, common carp, and rusty crayfish.

High groundwater loading, cold summer stream temperatures, and stable flows are key to the high-quality, self-sustaining trout fisheries that exist throughout much of the watershed. Cold water riverine habitat represents the key value of the Au Sable River system, and long- and short-term management goals should move toward protecting and restoring such habitat. Fish communities typical of high-gradient, cold water, large river habitats have been reduced or eliminated in areas where such habitats have been altered or impounded. Fragmentation of the river system has resulted in lost production of fishes, and reduced the potential of the river for supporting productive fisheries. Fish populations typical of natural lake outlets and habitats having gravel and rocky substrates have declined due to loss of these habitats. Management activities should attempt to restore connections between fragmented aquatic habitats and restore more natural rates of water, sediment, and woody debris delivery to Lake Huron.

The upper mainstem and its tributaries are largely free-flowing, and have supported nationally renowned fisheries for self-sustaining populations of brook trout, brown trout, and rainbow trout for the last century. However, the fisheries potential in portions of these streams is limited due to dams, shoreline development, low channel diversity from a lack of trees in the stream, excessive sedimentation, and a heavy load of sand in the channel. Management activities need to address these issues.

The lower mainstem has the potential for providing valuable fisheries for resident coldwater and potamodromous fishes. Its large size, high-gradient, and cold, stable flows would support major runs of Lake Huron fishes including chinook and coho salmon, steelhead (rainbow trout), brown trout, lake sturgeon, walleye, whitefishes, channel catfish, burbot, and various redhorse and sucker species. In the river’s free-flowing state, natural reproduction of chinook salmon and steelhead may be sufficient to support the Lake Huron fishery. The value of the potamodromous sport fishery that could be produced in the lower mainstem is substantial. In addition, much of this un-realized value would accrue to local communities along the river.

Primary impediments to achieving the river’s fishery potential are the six hydroelectric dams on the lower mainstem. The dams block fish migrations, warm the river, and replace high-gradient rapids with ponds having limited fishery management potential. Only about 7% of the mainstem and none of its tributaries (except the Pine River) are connected to Lake Huron. Dam removal and installation of fish passage structures at existing dams can help restore some fishery potential and economic benefits. Available studies and observational data on eagle, mink, and river otter suggest that passing contaminated Great Lakes fishes upstream would pose little or no significant harm to their populations.

The Au Sable River is a very popular choice among anglers and canoeists. Anglers throughout the United States come to fish the river’s wild trout stocks. Use by both anglers and canoeists is typically highest on high-gradient, riverine reaches, and puts a premium on this habitat type. Conflicts among groups using high-gradient reaches suggest the need for measures to prevent overuse and maintain a high-quality recreational experience. The high-gradient nature of the lower mainstem suggests that in a fully, free-flowing state it would have considerable recreational angling and canoeing potential. Present recreational use on lower mainstem ponds needs to be better documented to help guide management of the river.

As the future brings changes, it is important that the value of the Au Sable River to the region is kept, or enhanced. The many groups interested in the river have diverse ideas regarding the future of the watershed and how the river system should be managed. A basin-scale forum (watershed council) would provide a means for groups to work together at identifying important issues in the watershed, and developing a shared vision and a set common goals for the river’s future.

INTRODUCTION

This river assessment is one of a series of documents being prepared by Fisheries Division, Michigan Department of Natural Resources, for rivers in Michigan. We have approached this assessment from an ecosystem perspective, as we believe that fish communities and fisheries must be viewed as parts of a complex aquatic ecosystem. Our approach is consistent with the mission of the Michigan Department of Natural Resources, Fisheries Division, namely to "protect and enhance the public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for benefit of the people of Michigan".

As stated in the Fisheries Division Strategic Plan, our aim is to develop a better understanding of the structure and functions of various aquatic ecosystems, to appreciate their history, and to understand changes to systems. Using this knowledge we will identify opportunities that provide and protect sustainable fishery benefits while maintaining, and at times rehabilitating, system structures or processes.

Healthy aquatic ecosystems have communities that are resilient to disturbance, are stable through time, and provide many important environmental functions. As system structures and processes are altered in watersheds, overall complexity decreases. This results in a simplified ecosystem that is unable to adapt to additional change. All of Michigan's rivers have lost some complexity due to human alterations in the channel and on surrounding land; the amount varies. Therefore each assessment focuses on ecosystem maintenance and rehabilitation. Maintenance involves either slowing or preventing losses of ecosystem structures and processes. Rehabilitation is putting back some structures or processes.

River assessments are based on ten guiding principles of Fisheries Division. These are: 1) recognize the limits on productivity in the ecosystem; 2) preserve and rehabilitate fish habitat; 3) preserve native species; 4) recognize naturalized species; 5) enhance natural reproduction of native and desirable naturalized fishes; 6) prevent the unintentional introduction of exotic species; 7) protect and enhance threatened and endangered species; 8) acknowledge the role of stocked fish; 9) adopt the genetic stock concept, that is protecting the genetic variation of fish stocks; and 10) recognize that fisheries are an important cultural heritage.

River assessments provide an organized approach to identifying opportunities and solving problems. They provide a mechanism for public involvement in management decisions, allowing citizens to learn, participate, and help determine decisions. They also provide an organized reference for Fisheries Division personnel, other agencies, and citizens who need information about a particular aspect of the river system.

The nucleus of each assessment is a description of the river and its' watershed using a standard list of topics. These include:

> **Geography** - a brief description of the location of the river and its' watershed; a general overview of the river from its headwaters to its mouth. This section sets the scene.
>
> **History -** a description of the river as seen by early settlers and a history of human uses and modifications of the river and watershed.

Geology and Hydrology - patterns of water flow, over and through a landscape. This is the key to the character of a river. River flows reflect watershed conditions and influence temperature regimes, habitat characteristics, and perturbation frequency.

Soils and Land Use Patterns - in combination with climate, soil and land use determine much of the hydrology and thus the channel form of a river. Changes in land use often drive change in river habitats.

Channel Morphology - the shape of a river channel: width, depth, sinuosity. River channels are often thought of as fixed, apart from changes made by people. However, river channels are dynamic, constantly changing as they are worked on by the unending, powerful flow of water. Diversity of channel form affects habitat available to fish and other aquatic life.

Dams and Barriers - affect almost all river ecosystem functions and processes, including flow patterns, water temperature, sediment transport, animal drift and migration, and recreational opportunities.

Water Quality - includes temperature, and dissolved or suspended materials. Temperature and a variety of chemical constituents can affect aquatic life and river uses. Degraded water quality may be reflected in simplified biological communities, restrictions on river use, and reduced fishery productivity. Water quality problems may be due to point source discharges (permitted or illegal) or to nonpoint source runoff.

Special Jurisdictions - stewardship and regulatory responsibilities under which a river is managed.

Biological Communities - species present historically and today, in and near the river; we focus on fishes, however associated mammals and birds, key invertebrate animals, threatened and endangered species, and pest species are described where possible. This topic is the foundation for the rest of the assessment. Maintenance of biodiversity is an important goal of natural resource management and essential to many fishery management goals. Species occurrence, extirpation, and distribution are also important clues to the character and location of habitat problems.

Fishery Management - goals are to provide diverse and sustainable game fish populations. Methods include management of fish habitat and fish populations.

Recreational Use - types and patterns of use. A healthy river system provides abundant opportunities for diverse recreational activities along its mainstem and tributaries.

Citizen Involvement - an important indication of public views of the river. Issues that citizens are involved in may indicate opportunities and problems that the Fisheries Division or other agencies should address.

Management Options follow and list alternative actions that will protect, rehabilitate, and enhance the integrity of the watershed. These options are intended to provide a foundation for discussion, setting priorities, and planning the future of the river system. Identified options are consistent with the mission statement of Fisheries Division.

Copies of the draft assessment were distributed for public review beginning in summer, 1995. Public meetings were held June 6, 1995 in Grayling, June 7, 1995 in Mio, and June 8, 1995 in Oscoda.

After receiving public comments, the draft was re-written and distributed for public review in December 1999. Written comments were received until March 2000. Comments were either incorporated into the assessment or responded to.

A fisheries management plan will be written after completion of this assessment. This plan will identify options chosen by Fisheries Division, based on our analysis and comments received, that the Division is able to address. In general, a Fisheries Division management plan will focus on a shorter time period, include options within the authority of Fisheries Division, and be adaptive over time.

Individuals who review this assessment and wish to comment should do so in writing to:

Michigan Department of Natural Resources
Fisheries Division
1732 M-32 West
Gaylord, Michigan 49735

Comments received will be considered in preparing future updates of the Au Sable River Assessment.

RIVER ASSESSMENT

Geography

The Au Sable River drains an area of northeast Lower Michigan encompassing 1,932 square miles into Lake Huron (Figure 1). Its watershed covers parts of eight counties: Otsego, Crawford, Montmorency, Roscommon, Ogemaw, Oscoda, Iosco, and Alcona. The Au Sable River begins at the confluence of Kolke and Bradford creeks, about 2 miles north of Frederic in northwest Crawford County, at an elevation of approximately 1191 feet above sea level. From here, the river courses about 153 miles before emptying into Lake Huron near the town of Oscoda at an elevation of 577 feet above sea level.

Physical and biological characteristics of the Au Sable River change considerably from its headwaters to mouth as it: receives tributaries draining independent catchments; flows through lakes and impoundments; and passes across different landforms having distinctive geologic characteristics (Seelbach et al. 1997). To reflect its changing nature, we will discuss the Au Sable River's mainstem using river mainstem valley segments (Figure 2) that approximate those delineated by Seelbach et al. (1997). Mainstem valley segments are thought to be ecologically distinct from each other, varying in characteristics, such as stream size, water quality, channel shape, and hydrology. These characteristics often change abruptly (and segment boundaries occur) at stream junctions, points where channel gradient changes, and boundaries of local landforms, such as moraines or former lake beds. Impoundments can also have a dramatic effect on segment characteristics, but were not included in this classification. Rather, the classification provides a picture of the potential of impounded river reaches. Descriptions of river mainstem valley segments delineated for the Au Sable River follow.

Headwaters to Wakeley Bridge

The segment drains an area downstream to Wakeley Bridge, encompassing both the river's headwaters and the East Branch Au Sable River. The river is relatively small, has extremely stable, groundwater dominated flows, and a coldwater fish community. The East Branch Au Sable River originates in Barnes Lake in north central Crawford County at an elevation of 1,209 feet, flows through River Lake, and then meanders south for about 15 miles before entering the mainstem in Grayling at an elevation of 1,119 feet.

Wakeley Bridge to Mio Pond

Between Wakeley Bridge and Mio Pond the mainstem grows considerably larger as it receives three major tributaries, the South Branch Au Sable River, North Branch Au Sable River, and Big Creek-South. The South Branch Au Sable River (37 miles long) originates in Russell Lake (elevation 1,150 feet), flows east through Lake St. Helen, then north and meets the mainstem at an elevation of 1,035 feet. The North Branch Au Sable River originates near Otsego Lake (elevation 1,270 feet), and flows east then south for about 27 miles before meeting the mainstem at an elevation of 1,009 feet. Big Creek-South originates in northwest Ogemaw County at an elevation of 1,180 feet, and meanders about 20 miles northward to the mainstem at an elevation of 975 feet. Gradient in this segment of the mainstem is somewhat less than the upstream segment. Flow, temperature, and fish community characteristics are typical of a medium-sized, cold water stream.

Mio Pond to McKinley Bridge

After being influenced by Mio Pond, the river flows eastward through a relatively narrow, glacial-fluvial valley toward McKinley Bridge. Gradient here is somewhat higher, and water quality and biological communities are that of large, cold-cool river.

McKinley Bridge to Five Channels Dam

The mainstem continues to flow through a narrow, glacial-fluvial valley. However, about 7 miles downstream of McKinley Bridge, the river turns southeast and descends rather steeply, cutting through end moraines, toward the former Lake Huron lake bed near the upstream end of the Five Channels Dam. Gradient here is higher than the upstream segment, with the steepest portions of the river being covered by Alcona, Loud, and Five Channels ponds. Water quality and biological communities vary within the segment as impoundments produce temperature conditions ranging from cold-cool to warm.

Five Channels Dam to Foote Dam

The Au Sable River gradually descends eastward through lacustrine sands and gravels through Cooke and Foote ponds. Impoundments throughout this segment provide cool water, lentic (lake-like) conditions.

Foote Dam to Lake Huron

Below Foote Dam, the river meanders about 10 miles and receives another major tributary, the Pine River, before emptying into Lake Huron. The mainstem here is a large, cool river that flows through its former delta and has a low gradient. The Pine River originates from a multitude of small, spring-fed streams from the hill country of south central Alcona County. These tributaries meander in a southeast direction for considerable distances before joining to form the Pine River. The Pine River then flows into Van Etten Lake and eventually empties into the Au Sable River about 2 miles upstream of its mouth. For the purposes of this assessment, we will refer to the stream connecting Van Etten Lake to the Au Sable River (Van Etten Creek) as the Pine River.

History

The Au Sable River and its watershed were formed as Wisconsinan glaciers retreated from the state. During the later stages of deglaciation (about 13,000-11,000 years ago), the upper Au Sable and Manistee (immediately to the west) river watersheds were surrounded by the Saginaw and Michigan lobes of the ice sheet (Holman 1995). Meltwater flowing from these glaciers carried away finer silts and clays, but could not transport heavier particles as readily. Over time, deep deposits of the heavier, coarse-textured sands, gravels, and cobbles accumulated in the upper watersheds of these two systems. The high permeability of these outwash deposits is the key to hydrologic stability of the Au Sable and Manistee rivers. In addition, the glacial drainage ways formed by these flowing waters, formed the river valleys for much of the present Au Sable and Manistee rivers (Farrand and Bell 1982). Streams flowing in well-defined, glacial drainage ways in the Au Sable River system include Kolke and Bradford creeks; the mainstem, East Branch, and North Branch Au Sable River; and South Branch Au Sable River.

The earliest archeological information of human inhabitants in the Au Sable River basin dates to the Archaic period, 7,000-500 BC. These people adapted to the changing ecosystems at the end of the last glacial retreat by using seasonally available fish, game, and food plants such as nuts (B. Mead, Michigan Department of State, Office of the State Archaeologist, personal communication). By 500 BC there was a change to a more sedentary life-style as people established camps for a season or more (Commonwealth Cultural Resources Group 1991). Larger camps, typically used during winter, were established along lower reaches of the Au Sable River and Great Lakes coast. Small camps, located further upstream and in upland areas, were used for shorter time periods, often when traveling, hunting, or harvesting seasonally available resources (B. Mead, Michigan Department of State, Office of the State Archaeologist, personal communication). A traditional spring lake sturgeon fishing camp, from about 600 AD, was discovered along the river below Foote Dam. However, sites containing fish bones may be fairly rare in the watershed, because bone preservation in sandy soils is very poor (R. Stearley, Calvin College, Department of Geology, Geography, and Environmental Studies, personal communication). An estimated 15,000 archaeological sites are within the basin, with 136 prehistoric (before 1800 AD) and 287 historic sites having actually been described (B. Mead, Michigan Department of State, Office of the State Archaeologist, personal communication).

Later inhabitants included people of the Ottawa and Ojibwa tribes, both major branches of the Algonquin Nation (Fasquelle 1954). The Chippewa and Ottawa referred to the Au Sable River using the name, Mud-au-bee-be-ton-ange which translates into “Flowing or coming from the interior to the lake” (Miller 1963). This term applied to both the river and the Indians who emerged from the interior after winter had passed, and moved to the lakeshore for the summer.

The Au Sable River and its tributaries provided a primary transportation route between villages and across the Lower Peninsula. An inland travel route from Lake Huron to Lake Michigan followed the Au Sable and Manistee rivers, making a short portage (1.5 miles) between the two via Lake Margrethe (formerly Portage Lake) and Portage Creek (Miller 1963). Another portage extended from the Au Sable River south and west to the Muskegon River. It ran up the South Branch Au Sable River, through Robinson Creek, across Long Crossway Swamp, and to the Cut River, a tributary to the Muskegon River.

The sandy banks and bed of the Au Sable River were noted by early explorers. The earliest recorded mention of the Au Sable River was found in the journal of a young French army officer who was placed in command of a fort near the present day Port Huron and dated May 26, 1688 (Miller 1963; Thornton 1987). He referred to it as the Riviere aux Sables or River of Sand. Others referred to it as the Sable or Sandy River (Miller 1963).

Little was recorded about early exploration of the river until about 1820 when the river started to regularly appear on maps of Michigan. In 1820, Lewis Cass’ expedition bound for the upper Great Lakes and Northern Mississippi region reached the lower Au Sable River. Several expedition members described the area in their journal accounts. David Bates Douglass recorded that they landed “in the mouth of a fine river called the Riviere aux Sables” (Thornton 1987). Trowbridge recorded, “This river is 30 yards wide at its mouth, and though its entrance is obstructed by a sand bar, it is very deep above; it is navigable for 6 miles for boats of considerable size, and to the headwaters which are about 60 miles from the lake [Huron], for canoes; its waters abound in fish particularly sturgeon, of which an abundance was presented to us by the natives, who reside here at all seasons of the year in considerable numbers” (Donaldson 1983). Schoolcraft recorded that Chippewas from a village 2 miles above the river mouth presented the party with “some fresh sturgeon (*Acipenser*), which are caught in abundance in that river [Au Sable]” (Donaldson 1983). Doty described the Au Sable River as “This is a fine stream, its waters are deep. One mile up its bottom is pebble, but at its mouth, sand bars obstruct the entrance so that boats with difficulty pass” (Donaldson 1983). Doty also mentioned there being “six Indian lodges on the river”.

Such fondness for the river was not shared by all however. On September 4, 1826, Indian Commissioner Thomas McKenny, while on a treaty-making excursion with Governor Lewis Cass commented on the “myriads of mosquitoes along the shore of the Au Sable River near its mouth [from immense cranberry swamps a few 100 yards beyond the river]" (Donaldson 1983). They "concluded to send up the river to an Indian settlement for some whitefish". McKenny stated, "I shall never think of La Riviere Au Sable without disagreeable sensations".

The fur industry prospered in the watershed for a relatively brief period. In 1828, the American Fur Company established a post at the town of Au Sable. After 12 years, however, the company pulled out of the area because of its dwindling fur supply (Thornton 1987).

Documented inland explorations of the Au Sable River's upper reaches lagged behind those along the coast. Indian descriptions of the lands to the north as "hundreds of miles of extensive shaking marsh", though largely untrue, may have discouraged such activities (Thornton 1987). A surveying expedition from Saginaw to Mackinaw led by Benjamin Williams helped to dispel such descriptions. In addition to describing forests along their route, the Williams' party traveled on the Au Sable River apparently along much of its length. The lower river was described as "a large, deep, swiftly running stream". While waiting for relief supplies to arrive, his party camped further upstream and attempted to spear fish for food. Williams noted, "Many fine large fish [thought to be Arctic grayling] were pierced by myself and others, but they invariably escaped as no fishing tackle or spears had been provided". When relief supplies had not arrived after 16 days, Williams and three men set out down the river by canoe to meet the relief party. They described the "tortuous windings of the river", and "an immense raft of driftwood entirely covering over the surface of the stream…[and] signs of Indians, where they had hacked trees years before…[to make] a portage to carry across". After meeting the relief party on the other side of this raft, Williams' learned that "They had already been thirteen days ascending the river and had made many portages, some of a considerable distance" (Miller 1963).

Before the Michigan's infamous logging era, a considerable fishing industry had developed at the mouth of the River. The fishery began in 1848, peaked with 42 boats in 1865, and declined abruptly to 6 boats in 1871 (Schneider and Leach 1979). MacDonald (1942) reported that "extensive whitefish and trout beds laid off the mouth the river" supported this "sailing fleet" up until the beginning of the twentieth century. The fishery primarily targeted lake whitefish, lake trout, and lake herring, with incidental (yet substantial) catches of walleye. Thornton (1987) said that whitefish, lake trout, herring, yellow pickerel (walleye), and perch were caught in Lake Huron near the Au Sable River.

Extensive lumbering began in the Au Sable River watershed in 1865, peaked around 1890, and ended at around the turn of the century (Schneider and Leach 1979). Between 1867 and 1883 over one and one-third billion board feet of logs were floated down the Au Sable River (Miller 1963). Early logging was along watercourses, where logs could be readily transported to streams for floating to downstream mills. Coming of railroads allowed lumbering to extend even further away from streams. Railroads transported logs either directly to sawmills, or to rivers where they could be floated to mills (Vincent 1962). Vincent (1962) described status of logging in the Au Sable River watershed over time: 1873- four logging dams built on the North Branch; 1879- first timber camp on the mainstem 20 miles below Grayling; 1890- much of area around Mio logged; 1885- extensive logging in area downstream of Grayling. Miller (1963) reported that the volume of logs floated down the Au Sable River peaked in 1890 with over one-third billion board feet being transported. Eight large mills were operating in the towns of Oscoda and Au Sable in 1892 (Day and Donahue 1951).

Wastes from lumber mills were reported to have affected the fishery at the Au Sable River's mouth. MacDonald (1942) reported that the fishing industry was "negligible" during the lumbering period. Fishermen claimed that this was caused by waste materials being deposited into the river, and carried down to Lake Huron. Lumbermen did not agree, but fishing improved when the use of the river for waste disposal stopped (MacDonald 1942).

However, the logging days in the watershed quickly came to an end. Day and Donahue (1951) mentioned the closing of the Pack mill in the Oscoda-Au Sable area later in 1892, and Vincent (1962) reported no logs being handled at the mouth of the river by the Au Sable and Oscoda Boom Companies after 1896. After being cut over, extensively burned, and often unsuccessfully farmed, much of the land in the watershed reverted back to the government for non-payment of taxes, and has since re-forested (Miller 1963).

Construction of a railroad to Grayling in 1873 and the discovery of Arctic grayling provided the impetus for development of a world-renowned, recreational fishery on the Au Sable River (Clark and Alexander 1984). The opportunity to fish for Arctic grayling "attracted anglers from most of the United States and fly fishermen from England and Scotland" (Day and Donahue 1951). McKinley (1933) stated that every summer from June to October sportsmen from the cities of Cleveland, Cincinnati, Buffalo, Toledo, Indianapolis, Chicago, and many other places came "in quest of" Arctic grayling. Peterson (1957) noted that the need for fishing guides on the Au Sable River was evident as anglers came from England, Scotland, Sweden, and Norway to fish for Arctic grayling. Several pioneer families became river fishing guides, floating clients down river in specially designed Au Sable River boats.

Arctic grayling, a member of the salmon-trout family, were very abundant, but highly susceptible to exploitation. In those days, it was easy to catch more than one hundred pounds of Arctic grayling daily (Huggler 1981), and anglers often did not reel in their catch until five fish were hooked at once (Day and Donahue 1951). Arctic grayling were essentially gone from the mainstem and its tributaries by the early 1900s (Vincent 1962; Miller 1963). During this time, the recreational fishery of the Au Sable River changed from being internationally renowned and centered on a unique Arctic grayling population, to one of regional importance for brook and rainbow trout populations first established through stocking (Vincent 1962). Runs of potamodromous rainbow trout from Lake Huron were also developing in the Au Sable River, with steelhead being common in the Grayling area (Stoll 1951; Michigan Department of Conservation 1966).

Early in the 20th century, the expanding human population of the Saginaw Basin created a need for more electricity. The high-gradient reaches of the Au Sable River were found ideal for the location of dams to generate electricity. Six hydroelectric dams were completed: Cooke-1911; Five Channels-1912; Loud-1913; Mio-1916; Foote-1918 and Alcona-1923 (Commonwealth Cultural Resources Group 1991). While these dams provided power for Bay City, Saginaw, and surrounding rural areas, they considerably altered the lower river and its fish community.

Improvements in transportation to and throughout the watershed have opened up the Au Sable River to various types of use. Fishing remains quite popular, with brown trout having replaced rainbow trout as the dominant salmonid in the upper Au Sable River since the mid 1920s (Peterson 1957; Michigan Department of Conservation 1966). Canoeing has become increasingly popular. The first Au Sable River canoe race from Grayling to the river mouth was held in 1947 (Peterson 1957). Swimming, camping, trapping, and hunting along the Au Sable River also continue to be popular outdoor activities. Increasing interest in and use of the river has led to concern among stakeholders on issues including point and nonpoint source pollution, various hydropower-related issues, water withdrawal, residential development, and conflict among river-user groups.

The recreational and aesthetic value of waterfront property has put a premium on these lands for residential development. Former lumbering communities such as Grayling, Mio, Oscoda, and Roscommon have developed into resort and recreation destinations. Residential development in riparian and upland areas has increased. Projected percent increases in numbers of people and second homes for counties of the Au Sable River watershed are among the highest in the state (Michigan

Society of Planning Officials 1995). The future course of the Au Sable River will depend on how communities and stakeholders within the watershed plan for and direct change.

Geology and Hydrology

The physical setting of the Au Sable River watershed, in particular its geology, climate and disturbance history, play the dominant role in determining the watershed's biological communities, present land use, and history of development. The geology (including soils and topography), climate, and land use of the Au Sable River watershed influence the amount and seasonal patterns of precipitation, and how that precipitation is routed to the river channel (by way of groundwater or surface runoff), and the river's flow characteristics, such as discharge volume, hydrologic stability, and water quality.

Surface Geology

The Au Sable River drains extensive deposits of sands and gravels that originated as glacial and ice-contact outwash (Figure 3). Over 82% of the catchment of the mainstem above Foote Dam is composed of outwash sand and gravel deposits (Fisheries Division, unpublished data). These outwash deposits are quite thick (100s of feet) in much of the watershed, but in a few areas maybe only one or two feet in thickness (Albert et al. 1986). They represent some of the largest, deep deposits of sand on the continent. The extreme permeability of these deposits allows nearly all precipitation to percolate down to the water table, and flow underground towards the stream channel. This is evidenced by the low density of stream channels in the upper portions of Au Sable River basin (Figure 1). However, in some areas clay subsoils near the surface cause the water table to be perched and produce large swamps (Albert et al. 1986). This happens around Houghton and Higgins lakes (located south and west of Roscommon), and is probably responsible for the wetlands in the upper reaches of the South Branch Au Sable River.

Outwash sand and gravel deposits compose a greater percentage of the Au Sable River basin than any other watershed of comparable size in Michigan (Figure 4). The Au Sable River's surface geology is most similar to that of the Manistee River, which has less outwash, more coarse moraines, and comparable hydrologic characteristics. The Muskegon River has a similar amount of coarse deposits in its upper watershed, but wetlands and lakes associated with clay deposits in its headwaters make it a considerably warmer river. The Kalamazoo and Thunder Bay rivers generally flow through flatter topography (especially in their lower reaches) and as a result, do not receive major influxes of groundwater as do the Au Sable and Manistee rivers.

Segments from headwaters to McKinley Bridge

Outwash sands and gravels dominate nearly all of the upper Au Sable River's major tributaries. These deposits make up all or nearly all of the watersheds of the mainstem upstream of the mouth of the South Branch Au Sable River, Big Creek-South, and the North, South, and East branches of the Au Sable River (Figure 3). Before logging and human settlement of the region, fire-maintained prairies and oak and pine savannahs covered extensive areas of the excessively drained, coarse-textured outwash plains in these catchments. Whitney (1986) estimated that jack pine forests in these areas burned over roughly every 80 years and mixed pine forests burned over every 120-140 years. In contrast, hemlock - white pine - northern hardwood forests on finer-textured moraines burned over at approximately 1200 year intervals (Whitney 1986). Further downstream, outwash sands and gravels compose over 90% of the catchment of the mainstem at McKinley Bridge. Isolated deposits of lacustrine clays north of the Mio Pond to McKinley reach of the mainstem hold moisture more readily and are now farmed (Figure 3).

McKinley Bridge to Five Channels Dam

The mainstem, flowing in a glacial outwash channel, cuts through a medium- to fine-textured moraine. Steep topography, clay banks, and abundant boulder and cobble substrates, associated with the moraine, are readily observed along this portion of the River's course. Former rollways to the river, steep unvegetated banks that logs tumbled down during the logging era, are especially noticeable along this stretch. The South Branch River, a minor tributary draining lakes and wetlands in a former outwash channel, enters in this reach.

Segments from Five Channels Dam to Lake Huron

The mainstem flows through relatively flat deposits of sands and gravels that were deposited by the Au Sable River and its glacier-fed precursor. Here the river receives waters of the Pine River, which drains these deltaic deposits and lacustrine deposits ranging from clay-gravel left by a higher, glacial Lake Huron. The high density of streams in the Pine River drainage shows that its surficial geology is not as porous as that of the upper Au Sable River (Figures 1 and 3). Medium and fine-textured glacial tills make up over 35% of this watershed and coarse-textured outwash and glacial tills compose only about 38% of the drainage (Figure 4).

Bedrock Geology

The bedrock geology of the Au Sable River basin is economically significant. Mississippian age rocks lie directly beneath glacial drifts across the entire Au Sable River basin (Dorr and Eschman 1970). The primary formations are the Antrim Shale and Niagaran reef formations (limestones and dolomites). The Antrim Shale and Niagaran formations are important because of their potential for producing oil and gas. Depths of glacial drifts above the bedrock range from about 600 feet near the Au Sable River's headwaters to about 200 ft near the river mouth. Depths from the surface of the land to the Niagaran formation vary from 6500-7500 ft in the western portions of the basin to about 3000 ft in the eastern parts of the basin. Roughly 3500-4000 oil or gas producing wells now are in the Au Sable River basin. (R. Henderson, Michigan Department of Environmental Quality (MDEQ), Geological Survey Division, personal communication)

Climate

The Au Sable River is in two climatic districts as defined by Albert et al. (1986). The Highplains district encompasses most of the watershed (in addition to the much of the Manistee and upper Muskegon river basins), but does not include for the former lake bed of Lake Huron (Figure 3) which is part of the Arenac district (Albert et al. 1986). Comparing averages for the two districts, the Highplains district had a shorter growing season by 18 days, 1.2 inches more annual precipitation, 0.8 inches more precipitation from May to September, and an average annual temperature that was 1.1 ^{o}F cooler (Albert et al. 1986). In addition to statistical summaries of the climatic districts, Albert et al. (1986) provided this verbal description of these two districts. Regarding the Highplains district:

> "Due to its inland location, northern latitude, and relatively high elevations, the district has the most severe climate in Lower Michigan. The growing season (115 days) is not only the shortest but also the most variable from year to year. Because lacustrine influence is less here than in districts to the west, temperature conditions are less predictable in spring and fall. There is a greater chance of late spring freezes, and midsummer frosts are not unknown. However, the growing season heat sum (2140^{o}C-days) is only slightly lower than in the adjacent Newaygo and Arenac Districts.
>
> "Winters are cold. The average annual extreme minimum temperature is -29 ^{o}C [-20^{o}F]. Because the district is less likely to come under the influence of warm air

masses, compared to districts in Region I [southern Michigan], cold spells tend to last longer. There is considerable snowfall.

"The district is climatically diverse, yet the pattern of variation among weather stations is irregular. Thus, it is difficult to justify distinguishing subdistricts on the basis of climate. Many of the observed differences appear to be related to physiographic patterns that repeat over the entire district. In general, weather stations in flat outwash areas have lower than average minimums at all seasons, suggesting that cold air may accumulate in these areas. Major river valleys, such as the Au Sable, are clearly cold air drainages. By contrast, some of the lakes found in the district are large enough to be moderating influences in their immediate vicinities. The northwestern part of the district receives the most lake-effect snowfall of any area in Lower Michigan. Total growing season precipitation is similar throughout the district, but the eastern side receives relatively more of its precipitation early in the growing season, whereas the western portion gets more rainfall late in the season… The weather station at Grayling is fairly typical of the district."

Regarding the Arenac District:

"… compared to the higher elevation Highplains District, the growing season is 20 days longer, but not much warmer. Precipitation is relatively uniform throughout much of the growing season. Winters tend to be intermediate in severity between the Saginaw [located just to the south] and Highplains Districts. The average annual extreme minimum temperature is -26 ^{o}C [-15^{o}F], much colder than the Saginaw District but warmer than the Highplains district.

"Climate varies gradually within the district in both north-south and east-west directions. Standish is a typical inland weather station; East Tawas is near Lake Huron."

Annual Streamflows

Long-term discharge records are maintained by the United States Geological Survey (USGS) at several locations in the watershed (Blumer et al. 1998). Mean annual flows in cubic feet per second (cfs), drainage areas, and time period of available data at locations on the mainstem having USGS streamflow gauges are: Grayling- 76.5 cfs, 110 mi^2, and 1943-93; Parmalee Bridge- 1108 cfs, 924 mi^2, and 1908-16, 1930-31, 1995-present; Mio Dam- 1006 cfs, 1361 mi^2, and 1952-present; McKinley Bridge-1260 cfs, 1513 mi^2, and 1996-present; below Alcona Dam- 1320 cfs, 1598 mi^2, and 1996-present; and Rea Road just below Foote Dam- 1536 cfs, 1739 mi^2, and 1987-present. Similar data for two tributaries of the river: East Branch Au Sable River- 44 cfs, 76 mi^2, and 1958-84; and South Branch Au Sable River at M-72- 229 cfs, 401 mi^2, and 1966-date. Comparisons among gauge stations of the mean discharge per square mile were not made due to differences in the period of record among stations. Seasonally high flows generally occur in March and April, and low flows usually happen in July and August.

Seasonal Flow

The flow stability of a stream is the variability in its discharge over periods of years, months, days, or hours. The frequency, timing, and magnitude of high flows determine stream channel characteristics, and are related to a river's water quality, temperature, and aquatic community (Poff and Ward 1989). In Michigan, streams with more variable flow regimes tend to have more actively changing stream channels, warmer summer water temperatures, fewer coldwater fishes, and greater year-to-year variation in fish reproductive success. Fishes in Michigan streams are adapted to streamflow conditions that are relatively stable on a daily, seasonal, and annual basis. In general, streams that have stable flows tend to have more fishes with specialized feeding habits, such as feeding on benthic invertebrates, other fishes, or surface insects (Poff and Allan 1995). Fishes in streams with stable flows are generally also less tolerant of silt and turbidity, and more commonly associated with coarser substrates than fish species more common in hydrologically variable streams. The stability, timing, and volume of streamflows have been shown to influence the reproductive success of warm-, cool-, and coldwater fishes (Starrett 1951; Coon 1987; Strange et al. 1992; Bovee et al. 1994; Nuhfer et al. 1994). Increased flow stability has been positively related to fish abundance, growth, survival, and reproduction (Coon 1987, Seelbach 1986). Habitat suitability studies have documented the importance of flow stability to many fishes, including pink salmon (Raleigh and Nelson 1985), largemouth bass (Stuber et al. 1982a), smallmouth bass (Edwards et al. 1983), walleye (McMahon and Nelson 1984), brook trout (Raleigh 1982), chinook salmon (Raleigh et al. 1986a), and brown trout (Raleigh et al. 1986b). Incorporating the need to maintain stable flows in land use plans will help support the balanced and diverse fish communities in Michigan streams (Richards 1990).

The Au Sable River has one of the most stable flow regimes of any stream in the country. When compared to other USGS-gauged trout streams in the United States (N. L. Poff, Colorado State University, unpublished data), the Au Sable River (at Grayling) showed the least variation in flow among months, and had the lowest variation among daily flow values over the year (Figure 5). This stability results from the unusually large proportion of coarse-textured, outwash deposits in the river's catchment (see **Surface Geology**). The stream plotted closest to the Au Sable river on Figure 5 is the Manistee River which also drains coarse-textured outwash and morainic deposits.

The fact that the Au Sable River had an extremely stable discharge was not lost to early settlers. E.F. Loud, who ran a sawmill on the river stated that to the lumbermen, the Au Sable River was "an ideal servant, for its even, constant flow never failed to deliver in due season the logs that were entrusted to its care. It was often said in those days that the Au Sable River 'never hung up a drive'" (Loud 1981).

The 10:90% exceedence flow ratio provides an index of a stream's flow stability that is useful for comparing streams. The 10% exceedence flow is the discharge exceeded by the river 10% of the time and represents typical spring flows. The 90% exceedence flow is the discharge exceeded 90% of the time and represents summer or winter drought flow (base flow) conditions. Flow stability decreases with increasing values of this ratio. When compared to other similarly sized streams in Michigan the Au Sable River has extremely stable flow characteristics (Figure 6). The 10:90% exceedence flow ratio for the mainstem below Foote Dam is 1.91, just slightly below the 2.01 value for the Manistee River at High Bridge. Noting the hydrologic stability of the Au Sable and Manistee rivers, Richards (1990) classified both streams as "superstable". On the other hand, the Thunder Bay and Muskegon rivers have less coarse-textured deposits in their watersheds (Figure 4), and as a result, somewhat flashier flows (Figure 6). The fine-textured geology and agriculturally drained landscape of the Cass River watershed provides an even greater contrast, having 10% a exceedence flow that is over 25 times greater than its 90% exceedence flow. Of the gauged stream segments in the upper Au Sable River watershed, the mainstem at Grayling was the most stable, followed by the East Branch. The South Branch Au Sable River is somewhat flashier than the either the mainstem or the East Branch (Figure 6), and the flow stability of the North Branch is predicted to lie somewhere between that of the mainstem and South Branch (P. Seelbach, MDNR Fisheries Division, unpublished data).

The low-flow yield (90% exceedence flow divided by drainage area) provides a measure of groundwater loading to streams, and indexes a stream's flow stability, temperature characteristics, velocity conditions, and other physical conditions important to aquatic biota (Zorn et al. 1997). The

Au Sable River has an extremely high low-flow yield when compared to other similarly sized catchments in Michigan (Figure 7). The Manistee River, receiving groundwater influxes from adjacent high-elevation, coarse-textured moraines, has a higher low-flow yield. Catchments of other Lower Peninsula rivers, such as the Kalamazoo, St. Joseph, Thunder Bay, and upper Muskegon, lack the combination of coarse-textured glacial deposits and dramatic elevation changes needed for high groundwater inflows (Wiley and Seelbach 1997). As a result, these streams have somewhat flashier flow characteristics, and fish communities dominated by cool- and warmwater species.

Among the different tributaries of the upper mainstem, the North Branch Au Sable River, fed by an ice-contact moraine immediately west of its channel, had the highest low-flow yield (Figure 7). Its value of 1.03 cfs/mi^2 may be somewhat high however, because it was calculated from miscellaneous flow measurements, which were the only data available. The mainstem at Grayling, which flows in a narrow outwash between ice-contact deposits had the second highest low-flow yield. The East Branch Au Sable River had a somewhat lower value (also estimated from miscellaneous flow data), and still lower values in the South Branch Au Sable River and Big Creek-North. These tributaries are dominated by trout, especially in their lower reaches where the channel more deeply incises the water table (Figure 8).

Groundwater Inflows

High inflows of groundwater are key to the Au Sable River's stable flow regime, and are critical for providing suitable temperatures for coldwater fishes. Accrual of groundwater to the river does not happen at a constant rate along the river's entire length, but enters the river in discreet reaches. Identification of areas of high groundwater influx will help to ensure their protection, aid in assessing the fishery potential of altered (dammed) river reaches, and enable biologists to better target coldwater fishery management activities. High groundwater inflows to streams occur in areas having coarse-textured glacial deposits, which enable lateral groundwater movement, and high elevation differences, which provide a hydraulic head for downslope transport of groundwater (Wiley et al. 1997).

Coopes et al. (1974) noted such areas in the Upper Au Sable River by measuring the streamflow at several points along the length of the stream (Table 1). River reaches where there are unusually high groundwater inflows were from Burton's Landing to Wakeley Bridge on the mainstem; from County Road 612 to Robinson Dam on the East Branch Au Sable River; from Smith Bridge to the Oxbow Club on the South Branch Au Sable River; from the Ford to County Road 612 on the North Branch Au Sable River. Interestingly, a downstream loss in discharge to the water table was noted in the South Branch Au Sable River between the Oxbow Club and the river mouth, 1.9 miles downstream. The discharge declined 25% from 178 cfs to 133 cfs in this short reach.

Comparisons of changes in discharge relative to changes in catchment area at USGS gauging stations along the lower mainstem also allow for identification of reaches having significant groundwater inflows. Under normal circumstances, stream discharge and drainage area should increase at the same rate downstream; for example, a 15% increase in drainage area should result in a 15% increase in streamflow. If stream discharge increases at a higher rate (25% for example), the difference is probably due to groundwater inflows. Conversely, if the discharge increases by a lower rate (such as 10%), streamflow is being lost to other areas, such as the water table. We used 90% exceedence flows for 1997 and drainage areas from Blumer et al. (1998). We used drainage area rather than stream length because it provides a better measure of stream size, especially for reaches where tributary streams enter.

Large influxes of groundwater appear to enter the lower mainstem in discreet reaches (Table 2). Increases in stream discharge (18.2%) and drainage area (18.6%) of the Au Sable River are similar from Parmalee Bridge to Mio Dam, indicating proportional increases in groundwater. However, an unusually large amount of groundwater enters the Au Sable River between Mio Dam and McKinley Bridge. Here, the river's flow increases by 16.8% while its drainage area increases by only 10.0%. The river appears to lose some of its flow (possibly to the water table or evaporation in Alcona Pond) between McKinley Bridge and Alcona Dam, because its drainage area increased by 5.3% while its discharge increased by only 2.7%. Another very large influx of groundwater to the Au Sable River appears between the gauging stations at Alcona and Foote dams. In this reach, stream discharge increased by 15.1% while drainage area increased by only 8.1%. Large springs emerge from the river valley's walls in some areas along this reach, one locally well known one being the Iargo Spring, about 1.5 miles downstream of Five Channels Dam.

Daily Flow

In natural streams, daily flow changes are generally gradual. However, hydroelectric operations and lake-level control structures can cause substantial daily flow fluctuations. Such fluctuations have been documented within the Au Sable River system. These daily fluctuations can de-stabilize banks, increase moving sediment bedloads, degrade instream habitat, strand organisms, and interfere with recreational uses of the river. Aquatic production and diversity are reduced by such daily fluctuations (Cushman 1985; Gislason 1985; Nelson 1986; Bain et al. 1988).

Historically, all hydroelectric projects on the Au Sable River operated as peaking projects. This meant that the projects generated flood flows during periods of peak electrical demand (generally 8 a.m. to 8 p.m.) and drought flows during non-peak periods (generally at night). Water level fluctuations were dramatic. For example, in 1924, Carl Hubbs, a University of Michigan fisheries professor, noted that water levels below Mio Dam fluctuated about 6 feet due to dam operations (Fisheries Division records). Incidents at hydropower facilities in more recent times also dramatically altered streamflows. Data from USGS gauging stations on the lower mainstem show instantaneous (short-term) flows of 7 cfs below Mio Dam in 1977 and 135 cfs below Foote Dam in 1993. These discharges represent 100+ and 10 fold deviations from the mean daily flow of the river for that day (USGS 1978; Blumer et al. 1994). Both resulted from activities at the dams.

On July 15, 1994, the Federal Energy Regulatory Commission (FERC) issued 40-year operating licenses for the six hydroelectric projects on the Au Sable River. Loud, Five Channels, and Cooke dams will be operated as "peaking" projects, while Mio, Alcona, and Foote projects will operate as "run-of-river". Run-of-river operations require that flows downstream of the projects be within +/- 5% of the flow (+/- 20% if affected by ice) recorded at gauges in riverine reaches upstream of the projects. In some cases, corrections are needed to allow for time of passage and water accretion between the upstream gauge and the dam. Still, unnatural and substantial daily fluctuations in streamflow may occur under present run-of-river operations, as evidenced by simultaneous measurements of stream discharge above and below Mio Dam after a recent storm event (Figure 9). In the reach upstream of the dam, the river's discharge gradually increases during most of the day in response to the storm event. Below Mio Dam however, the river's discharge increases abruptly (in about an hour), reaching a high level, and then abruptly falls. Several abrupt increases and decreases in flow occurred during this time period due to dam operations and an inspection. Such changes may be partly responsible for the poorly-developed benthic invertebrate community (see **Biological Communities**) below Mio Dam, which has attempted to operated at run-of-river since about 1964 (Coopes et al. 1974).

The regulation of flows at outlets of inland lakes can also affect the rate at which daily streamflows change. Deviation from the natural, gradual patterns of daily flow changes are often detrimental to aquatic biota. Lake-level control structures often discharge large amounts of water into relatively small streams. Such unnatural discharges can result in considerable adjustment of the stream channel (erosion and sedimentation) and damage to aquatic communities. For example, the lake-level control structure at the outlet of Lake St. Helen, the headwaters of the South Branch Au Sable River, has been a concern for some time. Long-term monitoring of flows and fish populations in downstream reaches of the South Branch Au Sable River by the USGS and Michigan Department of Natural Resources (MDNR), Fisheries Division documented the effect of a dramatic increase in spring streamflow on the reproductive success of brown trout. On May 23, 1991, South Branch Au Sable River flows increased from 319 cfs to 561 cfs with no apparent change in inflows to the lake. Reports (D. Smith, MDNR Fisheries Division, personal communication) indicated that addition and removal of stoplogs used for maintaining water levels caused downstream navigational problems and substantial loss of brown trout recruitment (Nuhfer, et al. 1994). The issue of how the water level of Lake St. Helen should be maintained was settled May 5, 1998 by Roscommon County Circuit Court (file number 97-8080-CE). The order required that boards can only be added or removed when changing between court-established summer and winter lake levels. Many other lake-level control structures exist within the Au Sable River watershed (see **Dams and Barriers**). Investigation is needed to document the effects of these structures on the flow stability and aquatic communities of downstream reaches.

Soils and Land Use Patterns

Soils and Sedimentation

Soils in the Au Sable River watershed are predominantly sands, with over 90% being categorized as sands, loamy-sands, or wet-sandy-organic (P. Seelbach, MDNR, Fisheries Division, unpublished data). These sands are fairly unconsolidated, with poorly developed organic layers, and often vulnerable to erosion. Not surprisingly, sedimentation of streams continues to be a major issue in the watershed. Whether in transport or accumulating on the streambed, sediment adversely affects aquatic invertebrates and fishes typical of moderate-gradient, cold water streams (Alexander and Hansen 1983; Alexander and Hansen 1986). Sediment smothers gravel and cobble habitats critical for reproduction and survival of many fish and invertebrate species, and fills in pools that are used by larger fish. This results in habitats that are less diverse and less suitable for many fishes (Alexander et al. 1995). The stable-flow, low-gradient nature of streams in the Au Sable River system makes them especially vulnerable to increased sedimentation, because they lack the power (stream power = discharge x gradient) to quickly flush out sediment once it enters. Once sediment, particularly sand, is introduced into these streams, it tends to remain for several decades. Eliminating and preventing excessive erosion are important to the well being of the Au Sable River.

Though erosion is a natural process, past and present human activities have dramatically accelerated the rate of erosion of the landscape. Historic logging activities dramatically increased sedimentation rates. Cutting forests, rolling logs into streams, and transporting them downstream to sawmills introduced tremendous amounts of sediment into the system. Even very small streams were dammed for use in logging. Managed flood surges used to push logs downstream further enhanced erosion rates. Sediment introduced by these activities may still be slowly working its way downstream. Raw banks continue to contribute sediment in some areas of the watershed, though actions have been taken to re-stabilize many. Discharge to the river increased in response to reduced evapotranspiration by vegetation remaining on the cutover land. Peaking of hydropower plants dramatically increased the discharge and erosive power of the river (see **Modifying Factors**). Recent FERC licenses to the projects are helping to reduce some of their effects (see **Special Jurisdictions**).

Sources of sediment to the river presently occur at unvegetated stream banks and road-stream crossings. In the late 1980s and early 1990s, Huron Pines Resource Conservation and Development Area Council, Inc. (RC&D) inventoried erosion sites along the mainstem (376), South Branch (50), North Branch (10), East Branch (8), Big Creek-South (5), and Big Creek-North (9) identifying 458 sites in the watershed. One hundred and forty-eight of these were stabilized, including all or nearly all of the “severe” sites, and most of the “moderate” sites. It is estimated that this work reduced sediment delivery into the Au Sable River by about 85% (B. Benjamin, Huron Pines RC&D, personal communication), hopefully closer to more natural rates. Ten sediment traps are periodically excavated (in the East, South, and North branches of the Au Sable River, Big Creek-South, and the mainstem above Wakeley Bridge) to remove sediment now in transport.

Runoff from improperly designed or maintained road-stream crossings, especially county dirt roads, provides an ongoing source of sediment to the system. There are 978 road-stream crossings in the Au Sable River Watershed (Huron Pines Resource Conservation and Development Area Council, Inc. 1996). Huron Pines RC&D examined 343 of them in the Crawford, Oscoda, Ogemaw, and Alcona county portions of the watershed. Numbers of crossings in categories for severity of erosion were: severe-18; moderate-198; and minor-127 (Huron Pines Resource Conservation and Development Area Council, Inc. 1996; Huron Pines Resource Conservation and Development Area Council, Inc. 1997). This inventory is useful for prioritizing sites for remediation activities, and highlights the need for better road-stream crossing design and maintenance. Twenty-one sites have been remediated as of 1998, including nearly all of the severe sites (B. Benjamin, Huron Pines RC&D, personal communication). An inventory of the remaining 675 road-stream crossings is needed.

Reducing sediment contributions from road-stream crossings involves both education and funding. Incorporation of Best Management Practices (BMPs) for road siting, construction, and maintenance requires training of workers. Topics for discussion should include: ecological and economic effects of sediment on streams; how to properly site road-stream crossings; selection of crossing type and dimensions; recommended grades at crossing and approaches; and ways to minimize sediment delivery from grading and snowplowing. In addition, incorporation of some BMPs, such as those for bridge construction, may protect a stream and save money in the long run, but involve more up-front costs. This is especially problematic for county road commissions in the Au Sable watershed, many of which operate on relatively limited budgets (W. Taft, MDEQ-SWQD, personal communication). In such instances, partnerships between environmental groups and road commissions could provide funding for incorporation of BMPs. Road-stream crossings of State Forest roads are especially in need of financial help, because there is now no fund (budget allotment) for road maintenance (W. Taft, MDEQ-SWQD, personal communication).

Runoff from poor forestry practices can also deliver much sediment into streams. Anonymous (1994) provides guidelines for timber management that address issues such as: harvest planning; road and skid trail planning, construction, and drainage; equipment operation; and use of riparian buffer strips.

Improper urban development activities can dramatically increase sedimentation in streams. Temporary sediment loads from unprotected construction sites are often 500 times those of undisturbed lands (Toffaleti and Bobrin 1991). Paving within a watershed adds impervious area and increases the rate of delivery of water from the landscape to the stream, giving the river more erosive power. Michigan publications providing guidelines for minimizing sediment contributions to streams from road-stream crossings, forestry practices, and construction activities include Benjamin and Smith (1998), Anonymous (1994), and Peterson et al. (1998).

Past and Present Land Cover

Though land use is fairly similar to what it originally was (compared to other areas of Lower Michigan), the vegetative nature of the Au Sable River landscape is considerably different now than when the area was first settled (Comer et al. 1995). The excessively well-drained, coarse-textured soils of Au Sable River's watershed supported a conifer-dominated forest that was maintained by relatively frequent fires (see **Geology and Hydrology**). Prairies and savannahs, some 5-10 miles across, occurred in relatively flat areas along a swath of land running northeast from Higgins Lake to East and West Twin Lakes near Lewiston (Comer et al. 1995). More isolated savannahs were on other flat, sandy areas throughout the watershed. Originally, about 85-90% the Au Sable River basin consisted of conifer-dominated forest and prairie-savannah habitat (Comer et al. 1995); today these areas compose roughly 35-45% of the land area (based on 1978 state-wide land cover data from Michigan State University-Center for Remote Sensing). The only predominantly deciduous forests were in areas of fine-textured tills, end moraines, and former lakebeds (Figure 3). Lowland conifer forests were in the moist, organic soils of river floodplain habitats, with extensive tracts in the river valley roughly downstream of Alcona Pond. A large conifer and hardwood swamp occurred in the fine-textured glacial tills found in the middle portions of the Pine River watershed (Figure 3).

After the watershed was logged, attempts were made to farm the landscape, but the sandy soil and extreme climate (see **Geology and Hydrology**) made much of the watershed unsuitable for agriculture. As farms went bankrupt, much land was sold to the state and federal governments, or became tax delinquent and reverted back to the government (Miller 1963; Anonymous 1987). However, farming took hold in rare areas having flat topography and fine-textured soils, most notably just north of Mio and in the northeast portion of the Pine River watershed (Figure 3). Continued human presence changed the vegetative character of non-agricultural areas. Fire suppression has favored deciduous species over conifers in much of the watershed. For example, deciduous forests compose about 31%, and conifers make up about 46%, of the catchment of the Au Sable River upstream of Foote Dam (Figure 10). The original tracts of savannah-prairie habitat, once very abundant in the watershed, have been reduced to relatively few, very small, isolated openings, leading to the current rarity of their flora and fauna (see **Biological Communities**).

Over 80% of the Au Sable River watershed is forested. These forests provide habitat and food for wildlife, in addition to their aesthetic and recreational values. Riparian forests help stabilize stream banks, shade stream channels (maintaining lower water temperatures), provide organic material (nutrients) to streams, and provide large woody debris to the stream channel which serves as habitat for aquatic organisms.

The dominant plants vary with landforms in the watershed. Low-lying areas and areas along river valleys have higher water tables, organic soils, and poor drainage. They support shrubs, deciduous trees (e.g. ash, red maple, balsam poplar, and tag alder), and lowland conifers such as white cedar, balsam fir, tamarack, and black spruce. Moderately well drained habitats (fine and medium-textured geology) support northern hardwoods (beech, maple, birch, aspen, oak) and red pine, jack pine, or white pine. Excessively well-drained habitats (coarse-textured geology) support species such as jack pine, red pine, pin oak, and white pine. Many species of wildlife seasonally use, and move between, these habitats.

Land Use

The early history of the Au Sable River landscape provides the basis for today's land use patterns. Having little agricultural potential, upland areas were identified as most suitable for recreation and forestry (Miller 1963). Today 80% of the land draining to the mainstem at Foote Dam is forested, and about 6% of the area under agricultural or urban use (Figure 10). Agriculture makes up 23% of the land use in the Pine River drainage, and 9% in the North Branch Au Sable River (upstream of Kellogg's Bridge), but less than 4% in catchments of other tributaries. Considerable range (abandoned field) habitat occurs in catchments of most Au Sable River tributaries. Forest regrowth is now in much of this habitat. Major landowners in the watershed (and percent of the watershed owned) include the State of Michigan (36%), the United States Forest Service (30%), and Consumers

Power (1%) (MDNR, Spatial Information Resource Center, unpublished data). The remaining lands are privately owned and mostly used as permanent or seasonal residences and recreational property.

Forests in much of the Au Sable River basin are actively managed for timber production. Forest management practices have the potential to influence the river in a variety of ways. Cutting practices and the age and type of vegetation being managed (such as conifer forest, hardwood forest, or grassland), through their effect on total evapotranspiration by forests in the watershed, can strongly influence the total and seasonal yield of water to the river (Urie 1966a; Urie 1966b; Hibbert 1969; Urie 1977; Berry 1992). Given the magnitude of vegetative changes in the basin through time, changes in water-yield could be expected for the Au Sable River system.

The State of Michigan (Au Sable State Forest) and United States Forest Service (Huron-Manistee National Forest) manage approximately 66% of the watershed (MDNR Spatial Information Resource Center, unpublished data). In addition to their timber production value, these lands provide important recreational areas, provide public access to the river, and bring large amounts of riparian land under public management. No formal management plan for the Au Sable State Forest has been prepared. However, all management activities, including timber production, recreation, and land use, are planned by the MDNR Forest Management Division through a process that allows for comment from various agencies and the public. The intent of the United States Forest Service (USFS) Huron-Manistee National Forest Land and Resource Management Plan (United States Department of Agriculture, Forest Service 1986) is to provide direction for multiple use management and sustained yield of goods and services from national forest system lands in an environmentally sound manner.

Though much of the watershed remains forested, considerable riparian frontage has been developed for residential use. In many areas, riparian forests have been cleared, stream bank habitats have been altered, and delivery of large woody debris to the river has been reduced. Riparian habitats serve many valuable roles as discussed by Large and Petts (1994). They provide important habitats for flora and fauna, being areas of high biological diversity and productivity, and are important as sources for species dispersal. They regulate river ecosystem dynamics by: influencing movement and migration of animals; controlling surface runoff; regulating sub-surface flows; providing organic matter to the river (including large woody debris); and storing water within the floodplain. They enhance the ecological diversity of the floodplain by providing a variety of habitat patches. In addition, undeveloped riparian corridors enhance the aesthetic and recreational value of the river. Protection of existing riparian corridor habitat and rehabilitation of human affected riparian habitats should be pursued whenever possible.

Residential development and growth within the watershed is proceeding at a rapid pace (Michigan Society of Planning Officials 1995). Population estimates for the basin for different years were: 1960-15,442, 1970-21,017, 1990-57,180 (Coopes et al. 1974; USGS 1998). In terms of expected percentage increase in population between 1990-2020, 3 of the 4 fastest-growing counties in Michigan are in the Au Sable River watershed; Otsego-93%, Montmorency-85%, and Crawford-72%. Populations of Oscoda, Roscommon, and Ogemaw counties are expected to increase by more than 56%, and a 0-20% increase is anticipated for Alcona and Iosco counties. From 1960-1990, the number of second homes in Crawford, Oscoda, Roscommon, and Alcona counties has increased by more than 100%. Between 1990 and 2020, the number of second homes in counties within the watershed is expected to increase by at least 40% in all counties of the basin. Local units of government are already facing issues of large residential development projects being built in previously undeveloped, forested landscapes. Such local governing groups may have never had such projects proposed to them before, and may be somewhat unprepared for all that is involved. Communication on these issues between more- and less-developed local governmental units within (or outside) the watershed would help to ensure that development occurs in a way that provides long-term benefits to the community and does not unduly harm the river's unique and fragile hydrologic characteristics. Such communication could be greatly facilitated by formation of a locally-based, Au Sable River watershed council.

Other than in the Natural River zoning district (see **Special Jurisdictions**), land development in many portions of the watershed is not regulated due to a lack of zoning regulations and enforcement. Clinton, Elmer, and Big Creek townships, which make up half of Oscoda County, are not zoned. Other counties, such as Montmorency, Ogemaw, and Otsego, have zoning at the county level, but not at the township level.

Urban development can affect aquatic environments in a variety of ways as discussed by Hay-Chmielewski et al. (1995):

> "Landscape development for urban use also has dramatic effects on the aquatic environment (Leopold 1968; Booth 1991; Toffaleti and Bobrin 1991). Development noticeably increases the percentage of impervious land area, resulting in more water reaching the stream channel more quickly as surface runoff. Urban and higher-density suburban areas typically have 50-100% and 25-45% impervious surface areas, respectively (Toffaleti and Bobrin 1991). Impervious surfaces include pavement (roads and parking lots) and roofs of buildings. These have runoff coefficients 6-14 times greater than for undisturbed land (Toffaleti and Bobrin 1991). Engineered stormwater runoff systems also speed surface runoff. Increased runoff causes greater peak flows, harmful to reproduction and survival of many aquatic organisms, more erosion, decreased groundwater recharge and thus base flow, increased summer temperatures, and decreased available habitat (Leopold 1968; Booth 1991). Development that brings the construction of wells reduces groundwater table levels and stream summer base flows, with a resulting increase in water temperature and decrease in available stream habitat. Following use, most of this water returns to the system as heated surface water, causing increased and more variable water temperatures.
>
> "Temporary sediment loads that erode from unprotected construction sites are frequently 500 times those of undisturbed lands (Toffaleti and Bobrin 1991). Sediments that reach stream channels clog and bury clean gravel and cobble substrates critical for many invertebrates and fish species. Sediment loads from improperly placed or maintained road crossings can also be a major input to the system. Runoff from impervious surfaces carries pollutants including nutrients, bacteria, metals, litter, oil and grease, herbicides and pesticides, and salts. Osborne and Wiley (1988) have shown that urbanization is the primary cause of increasing summer nutrient concentrations in [Midwestern] rivers."

Oil and Gas Development

Extraction of oil and gas occurs in roughly 70% of the basin, with about 3500-4000 wells (R. Henderson, MDEQ, Geology Division, personal communication). Most development is now happening in the Antrim formation, with little new development in the Niagaran formation. The following is a general summary of oil and gas development status in the counties that compose the bulk of the watershed. Southern Otsego County is fully developed. In Crawford County, the Niagaran is mostly developed and the Antrim has only been developed with much success in its northern portions. Roscommon County is mostly underlain by Ellsworth Shale, has no Niagaran reefs, and its Antrim gas deposits cannot be readily extracted. Most development occurred here in the 1930s and 1940s, and no new exploration is expected in the near future. Between 2/3 and 3/4 of the Antrim gas reserves of Oscoda and southern Montmorency counties have been developed. Development is active in Alcona and Iosco counties, with about 40-50% of their mineral resources having already been developed. Most activity is targeting Antrim deposits in the western portions these counties. (R. Henderson, MDEQ, Geology Division, personal communication)

Efforts to minimize the adverse effects of oil and gas development have met with fair success. Improved techniques have been developed for drilling and laying subsurface pipelines. Replanting work areas have reduced sedimentation, but work is needed to ensure that disturbed soils are quickly re-vegetated. Problems with excess noise from facilities have been addressed with varying degrees of success. Density of future wells is limited to one well per 80 acres. Increased spacing of wells and use of angular drilling techniques would reduce the density of well pads and resulting sedimentation. Regulations have been passed that require on-site containment of accidental spills. Most spills from the past (20-40 years ago) have been, or are nearly, cleaned up. However, erosion damage resulting from illegal use of pipeline right-of-ways and access roads by off road vehicles is a concern. Concerns still exist regarding groundwater contamination due to improper containment of drilling fluids, disposal of cuttings from drilling activities, equipment lubricant spills, and leaks from deteriorating flow lines. Potential sedimentation from new roads, well pads, and flow and sales lines is also a cause for concern. Continued vigilance is needed to minimize the effects of oil and gas development on the Au Sable River's sensitive surface- and groundwater resources. The need to protect groundwater resources from contamination is especially critical when exploiting oil-rich formations, such as the Niagaran. (R. Henderson, MDEQ, Geology Division, personal communication)

Channel Morphology

Channel Gradient

River gradient, together with flow volume, is one of the main controlling influences on the structure of river habitat. Steeper gradients allow faster water flows with accompanying changes in depth, width, channel meandering, and sediment transport (Knighton 1984). In the glaciated Midwest, high stream gradients often occur where streams cut through end moraine deposits. When the deposits are coarse-textured (e.g. sands or gravels) and elevation changes are large, stream channels receive high inflows of groundwater (Wiley and Seelbach 1997). In this way, stream gradient is related to other important variables such as stream temperature, current velocity, bottom substrate, and flow stability, and is especially important to coldwater fishes (Zorn et al. 1997). Gradient has also been used to describe habitat requirements of cool- and warmwater fish species including smallmouth bass (Trautman 1942; Edwards et al. 1983), largemouth bass (Stuber et al. 1982b), northern pike (Inskip 1982), white sucker (Twomey et al. 1984), black crappie (Edwards et al. 1982), blacknose dace (Trial et al. 1983), and creek chub (McMahon 1982).

Gradient is measured as elevation change in feet per river mile. As the character of the landscape changes along a river's course, some portions of a river drop more steeply than others. These areas of different gradient create a variety of stream channel habitats for fish and other aquatic life. Typical channel patterns in relation to gradient (G. Whelan, MDNR Fisheries Division, unpublished data) are shown below. In these descriptions, hydraulic diversity refers to the variety of water velocities and depths found in the river. The best river habitat offers a wide array of depths and velocities to support various life functions of different species. Fish and other life are typically most diverse and productive in those parts of a river with gradient between 10 and 69.9 feet per mile (G. Whelan, MDNR Fisheries Division, unpublished data; Trautman 1942). Such gradients are rare in Michigan because of our low relief landscape. High-gradient stream reaches that did occur in the state were sites for dams.

Gradient Class	Value (ft/mi)	Channel Characteristics
Low	0-2.9	Mostly run habitat with low hydraulic diversity.
Medium	3-4.9	Some riffles with modest hydraulic diversity
High	5-9.9	Riffle-pool sequences with good hydraulic diversity.
Very High	10-69.9	Well established regular riffle-pool sequences with excellent hydraulic diversity
	70-149.9	Chute and pool habitats with only fair hydraulic diversity.
	>150	Falls and rapids with poor hydraulic diversity.

Compared to other Michigan rivers, the Au Sable River has considerable gradient. The average gradient of the mainstem is 3.9 ft/mi, one of the highest of similar-sized streams in Michigan's Lower Peninsula (Figure 11). Gradients (in ft/mi) of other mainstem rivers are: Muskegon- 2.6 (O'Neal 1997), Manistee- 2.95 (Rozich 1998); and Huron- 2.95 (Hay-Chmielewski et al. 1995). On the mainstem, low gradient composes 71 river miles (46%), and medium gradient represents another 50 miles (32%) (Figure 12). The higher, and more desirable, gradient occurs over relatively short reaches of the river. High gradients make up 19% (29 miles) of the mainstem, and very high gradients (>10 ft/mi) are found in only 5 miles (3%). However, about 59 miles (38%) of the mainstem are impounded by dams (Figure 12), including 19 miles (24%) of the high-gradient water, and 3.8 miles (78%) of the very high-gradient class.

The lower mainstem contains some of the highest gradient reaches of any large, cold water river in the Lower Peninsula, making this a rare and valuable resource (Table 3). Included are 16 miles of high-gradient, and 3.8 miles of very high-gradient water. Much of this extremely rare and biologically valuable habitat is impounded by dams (Figure 13). All of the >10 ft/mi water on the lower mainstem is impounded by Alcona and Five Channels dams (Table 3). Forty-nine percent of the 5-9.9 ft/mi reaches are also impounded. The only relatively high-gradient riverine reach remaining is a 0.8 mile stretch of the Au Sable River upstream of Loud Pond that has a gradient slightly less than 9 ft/mi. In this short reach are found well-developed rapids, deep pools, rocky substrates, high banks, gravel and cobble bars, and groundwater inflows. Returning high-gradient reaches to a free-flowing state would restore these unique and rare, lost habitats.

The existence of very high-gradient reaches in the lower mainstem is important when considering management of fishes (particularly coldwater fishes) in Lake Huron. The Au Sable River was a major spawning stream for large-bodied, riffle-spawning, cold-cool water fishes in Lake Huron (see **History** and **Biological Communities**). Now only about 10 miles (7%) of the mainstem Au Sable River, all which is low gradient, is accessible to Lake Huron fishes. In addition, the many tributaries to the mainstem would provide a diverse array of habitats for migratory fishes. Reconnection of Lake Huron to the higher gradient reaches of the Au Sable River and its tributaries is needed to more fully realize the productive capacity of the Au Sable River system.

River gradients are not uniformly distributed throughout the river. Rather, they reflect the landforms over which the river flows: lower gradients occur where the river flows across outwash-plains and former lake-plains; higher gradients result where it cuts through moraines. Gradients of the major mainstem valley segments of the mainstem are characterized as follows:

Headwaters to Wakeley Bridge

About 65% of the 31 miles in this stretch are medium to very high gradient. Gradient above Grayling is generally lower than that below the city. However, reaches near Frederic, former Salling Pond, and

Grayling Millpond have high gradient. The Frederic and Salling reaches had been previously dammed, and the Grayling Millpond is still impounded. High gradients predominate in the free-flowing reach of the mainstem from Grayling to Wakeley Bridge. Forty-three percent of this stretch has gradients >5 ft/mi, with some riffles exceeding 11 ft/mi.

Wakeley Bridge to Mio Pond

Gradient in this segment is somewhat lower, with only 2.6 of its 22 miles in the high class. Moderate and low gradients make up the remaining 38% and 50% of the segment. This entire segment is undammed and provides high-quality, cold water habitat.

Mio Pond to McKinley Bridge

The mainstem is considerably larger here, and gradient increases somewhat. High (15%) and moderate (41%) gradients account for much of the 25 miles of this mainstem valley segment. However, Mio Dam impounds 49% of the high-gradient habitat in the segment. A 5.3 ft/mi riverine reach is near Cauchy Creek.

McKinley Bridge to Five Channels Dam

Some of the most dramatic high-gradient reaches are in this mainstem valley segment, where the mainstem cuts through end moraines on its descent to Lake Huron. Of the 37 miles in this reach, 10% are very high gradient, and another 33% are in the high-gradient class. Impressive rapids formerly existed where Alcona and Five Channels Ponds now lie, with 2.4 miles of 11+ ft/mi rapids under Five Channels Pond. Similar rapids do not exist on any other large river in Michigan’s Lower Peninsula. Only 16% of this segment is low gradient, and 41% is moderate gradient. Unfortunately, all very high-gradient habitat is under impoundments, and only 43% of the 12.3 miles of high-gradient waters remain free-flowing. A 0.8 mile long, 8.9 ft/mi stretch just upstream of Loud Pond is the only remaining riverine reach on the lower mainstem with a gradient >8 ft/mi. A small, unnamed tributary enters the mainstem (upstream of Loud Pond) as an 8-10 foot high waterfall pouring over a vertical clay bank.

Five Channels Dam to Foote Dam

This entirely impounded, 30 mile long segment of the mainstem gently flows over lacustrine sands and gravels from an earlier, higher stage of Lake Huron. Hence, river gradients are less impressive. Low (75%) and moderate (25%) gradient classes compose the entire segment.

Foote Dam to Lake Huron

Gradients here are even lower, as the mainstem meanders across alluvial deposits. All 10 miles of this reach fall in the low gradient class.

Major Tributaries

East Branch Au Sable River

The East Branch Au Sable River flows in an outwash channel between ice-contact deposits along its entire length. It is mostly low gradient from its headwaters to former Robinson Dam, about 2 miles downstream of County Road 612 (Table 3). From here downstream, high gradients prevail with 7+ ft/mi gradients in the 4 miles upstream of the mouth of the East Branch.

South Branch Au Sable River

The South Branch provides several distinct riverine habitats along its length. In fact, Seelbach et al. (1997) identified three river mainstem valley segments for the South Branch Au Sable River. From its headwaters to about 2 miles upstream of Chase Bridge, the river has a low gradient, with nearly the entire segment being <3 ft/mi. From here to Canoe Harbor State Forest Campground (about 2 miles upstream of Smith's Bridge), gradients are medium to high as the river cuts through ice-contact outwash and glacial outwash deposits (Figure 3). Gradient remains high as the river cuts through more ice-contact outwash, and receives considerable groundwater (see **Geology and Hydrology**), before flattening out in its lowermost 2.3 miles.

North Branch Au Sable River

From about 5 miles below its source to its confluence with the mainstem, the North Branch Au Sable River has high gradients. Its overall gradient averages 7.1 ft/mi, in contrast with 4.9 ft/mi for the East Branch Au Sable River and 2.6 ft/mi for the South Branch Au Sable River. It flows adjacent to ice-contact outwash deposits along its entire length, and has gradients generally ranging from 5-16 ft/mi.

Channel Cross Sections

The characterization of habitat by gradient presented above assumes normal channel cross sections for such gradients. However, a variety of factors can cause channel cross sections to deviate from these characterizations. For example, unstable flows acting upon a stream channel whose bed is more resistant to erosion than its banks will often cause the channel to be overly wide and shallow, lacking large woody debris and structure (Heede 1980). Activities, such as log driving can increase bank erosion (see **History**). Overly narrow channels may result from dredging and channelization activities, or simply the existence of stream banks (natural or man-made) that are highly resistant to erosion. Sediment erosion and deposition associated with improper placement of bridges and culverts will also alter channel form. Detailed observations of channel cross-section can be used to identify where significant channel changes may have occurred.

Two quantitative measures of channel characteristics were determined from available data. First, channel widths were compared to the average width of rivers with the same discharge volume using relationships from Leopold and Maddock (1953) and Leopold and Wolman (1957). Channel widths were measured on the Au Sable River by USGS and Consumers Power Company during stream discharge studies. Cross-sections that were clear of bridges and most representative of the section were selected where possible. Expected width (ft) was calculated from measured discharge (cfs) using the relation $\log(\text{Width}) = 0.741436 + 0.498473 * \log(\text{Mean Daily Discharge})$. Measured channel widths were compared to predicted widths, and we noted when the measured channel width was beyond the expected range of widths.

Second, the hydraulic diversity of a channel can be indexed using the Shannon–Wiener information statistic (G. Whelan, MDNR Fisheries Division, personal communication). The greater the number of different velocities and depths, the larger number of species or life stages (i.e. spawning, young of year, juvenile, adult etc.) that a reach can support. Diversity indices were calculated from counts of cross-section data points in classes of velocity in intervals of 0.5 feet per second and depth in intervals of 0.5 feet. Hydraulic diversity categories and values are: Poor- 0-1.5; Fair-1.6-2.0; Good-2.1-2.5; and Excellent->2.5. Only sites having >15 sets of measurements were used, because this statistic is sensitive to low sample size. In addition, this statistic is somewhat biased in that the potential for high diversity increases with stream size.

Data from Coopes et al. (1974), and unpublished data from the USGS and MDNR Fisheries Division, were used to describe the Au Sable River's channel character. The reader is referred to Coopes et al. (1974) for excellent descriptions of the river during the early 1970s. Channel characteristics of the mainstem and some of its major tributaries are briefly characterized.

Headwaters to Wakeley Bridge

Much of the mainstem above Grayling consists of sand-dominated run habitat with a few pools and riffles. Relatively low diversity values at Old Dam Road and Pollack Bridge and a preponderance of sand suggest that the river may be carrying a considerable sand bedload (Table 4). However, sand in these areas may also relate to their low stream gradients. Better riffle-pool sequences and coarser substrates are associated with in higher gradient habitats such as downstream of Frederic, at former Salling Dam (between Grayling and Frederic), and below Grayling Millpond (Table 3). Grayling Millpond is covering the highest gradient reach of the mainstem above Grayling. Instream cover and shading, both provided by an old-growth riparian corridor, are lacking in much of the segment, but especially in the restored riverine reach upstream of Salling Dam.

For about 6 miles below the Grayling Dam, the mainstem is a low gradient stream, characterized by considerable sandy run habitat. Channelization for residential development in 1957 and I-75 bridge construction in 1960 had considerable effect on portions of this reach (Coopes et al. 1974). Between Canoe Camp and Wakeley Bridge, gradient increases and substrates are dominated by gravel and cobble as the river bumps against ice-contact outwash hills (Figure 3). Channel width from Grayling to Wakeley Bridge is neither consistently too wide or narrow (Table 4). More data are needed to better describe the river channel. Channel diversity values are, on average, somewhat higher than those upstream of Grayling, and show fair-good hydraulic diversity. Considerable residential development has occurred in the riparian corridor of this reach. In many areas, naturally vegetated stream banks have been replaced by seawalls or riprap. Consequently, undercut bank and root wad habitats have been lost. Clearing of riparian forests has reduced shading and contributions of large woody debris that diversify the channel by creating holes and logjams.

Wakeley Bridge to Mio Pond

This reach is characterized by an increase in size. Good riffle-pool habitats exist in higher gradient areas (Table 1), with gravel and cobble predominating. Deep pool habitats are more prevalent, especially where the thalweg of the river flows along clay banks. The North and South branches of the Au Sable River and Big Creek-South enter here, each contributing considerable sediment loads. Considerable sand-dominated run habitat is in this segment, most notably just upstream of the mouth of the South Branch Au Sable River (the Stillwaters) and a couple miles downstream of the mouth of the North Branch Au Sable River. Residential development, especially near Wakeley Bridge and between McMaster’s Bridge and the mouth of North Branch Au Sable River (about 2 miles downstream), has resulted in construction of seawalls and bulkheads and loss of riparian forest. Large woody debris, instream cover, and riparian shading are especially lacking in these areas, the Stillwaters area, and the lower third of the segment. Data are needed to evaluate channel width and hydraulic diversity throughout this segment.

Mio Pond to McKinley Bridge

Mio Pond covers the highest gradient rapids of this segment. The bed of channel in the rest of the segment is fairly well armored with coarse gravel, cobble, and boulder. The amount of large woody debris is somewhat limited, but should increase as the riparian forest grows older. However, Mio Dam prevents natural downstream transport of trees. The heavily armored streambed makes formation of pools around fallen trees and their retention in the channel more difficult. Interstitial spaces between cobbles and boulders, and deep holes carved by the river, provide cover for different sized fishes. The riparian corridor is heavily forested from Mio Dam to Comins Flats (about 7 miles above McKinley Bridge). From Comins Flats to McKinley Bridge, the substrate is mostly sand and gravel. Seawalls, riprap, and docks, associated with residential development in portions of this reach, constrain normal channel processes. Stream widths in the segment were neither consistently too wide or narrow, and hydraulic diversity was rated as good (Table 5).

McKinley Bridge to Five Channels Dam

About 51% of this segment is impounded by dams, including all the highest gradient rapids. Most remaining riverine reaches provide pool-riffle habitat and are dominated by coarser gravels, cobbles, and boulders. Clay is apparent along both the banks and bed of the stream, particularly below Alcona Dam. Clay functions as a hydrologic control in some areas, and provides bank strength, allowing formation of deep pools (up to 10 ft) at many river bends. The riparian corridor is fairly well forested, and instream large woody debris, though somewhat lacking now, will increase as the forest ages. Again, the presence of dams in this segment prevents natural transport of woody debris. Steep eroding banks in several areas have been stabilized to prevent further erosion. The South Branch River (Figure 1) delivers a significant amount of sediment into the mainstem above Loud Pond. The channel averages about 25 feet narrower than expected (Table 5). This may be attributable to various factors including the river's seasonal flow stability, the presence of clay deposits, and the glacially confined nature of the channel. Hydraulic diversity values rate the segment as excellent (Table 5).

Five Channels Dam to Foote Dam

This reach is entirely impounded by dams, but could provide low-gradient riverine habitat for many coolwater and potamodromous fishes from Lake Huron.

Foote Dam to Lake Huron

This segment is nearly all run habitat with a few riffle-pool and run sequences. The riffle areas are located <3 mi below Foote Dam, at the Highbanks and Boy Scout Camp. The riffle-pool habitat is mostly gravel and cobble, and the run habitats are dominated by sand with some gravel. A number of the river bends were cut off during the logging period to shorten the river. Severe bank erosion and slumping, particularly between the Highbanks and Whirlpool access sites (3-7 mi below Foote Dam), cause excessive sand bedload in this segment. Many slumping banks are within a few miles upstream and downstream of the mouth of the Pine River. Channel constraints, such as sea walls and riprap from residential development, are nearly absent from this segment until the confluence with the Pine River (Van Etten Creek). Large woody debris is present from Rea Road to the Highbanks, probably from bank slumping, but is lacking in the river below the Highbanks. Riparian shading is fair to poor through this reach. Channel widths were within the range of expected values (Table 5).

Major Tributaries

Most of the major tributaries of the Au Sable River share several features. Their upstream reaches typically are sandy runs, with riffle-pool sequences and gravel becoming more common further downstream as they fall into the main river valley. All areas have been logged. Consequently, instream cover provided by large woody debris is lacking and the young second growth (or later) forest often provides limited shading. In certain areas, streamside residential development has resulted in removal of woody debris from streams, loss of vegetated stream bank habitat due to seawall and riprap installation, and reduced shading and contributions of large woody debris. Increased erosion of uplands has caused many streams to carry a heavy bedload of sand.

East Branch Au Sable River

This stream is nearly all sandy run habitat with a few riffle-pool sequences. It has fair amounts of small and medium sized woody debris, but large woody debris is lacking. Shading is fair due to a relatively young riparian forest. It received a heavy load of sand during I-75 bridge construction (Coopes et al. 1974). Measurements (Table 4) indicate a channel that has fair hydraulic diversity and is somewhat narrower than expected.

South Branch Au Sable River

From its headwaters to Roscommon, this tributary drains considerable wetlands, and it has sand and muck substrates and little large woody debris or shade. From Roscommon to Chase Bridge, run habitat typifies the upper reaches with more riffle-pool habitat downstream. The channel is constrained by shoreline development in this reach and shading is limited. Fair to good cover, riffle-pool habitats, and an entirely forested riparian corridor characterize the river from Chase Bridge to Smith Bridge. From this point to the South Branch's confluence with the mainstem the river flows gently in the former river valley of the mainstem. It is predominantly a sandy run with little large woody debris, instream cover, or shade. Channel width data (Table 4) suggests that the channel is somewhat wider than normal at Chase Bridge, but within the expected range, and somewhat narrower than expected at the Castle. Both sites had good hydraulic diversity.

North Branch Au Sable River

Sandy run and riffle habitat are typical for much of the North Branch Au Sable River (Figure 1). Gradient is high and substrates are generally coarse due to ice-contact outwash deposits in the river valley and immediately west of the river channel (Figure 3). Logging effects are especially apparent in this tributary from about 2 mi downstream of Turtle Creek to about 5 mi downstream of Lovells (Dam 4). Here the channel is shallow and overly wide, large woody debris is lacking, hydraulic diversity is only fair (Table 4), and logging dams remained well into the 20^{th} century (Coopes et al. 1974). Mid-channel and island habitat improvement structures appear to have widened the channel in many areas. The riparian forest here is young and provides relatively little shade and woody debris to the stream. To improve this reach for large salmonids, additions of large woody debris (whole trees) should be made along stream banks, with the intent of narrowing and deepening the channel; large, mid-channel or island-type structures should not be used. Bridges are partly responsible for the river being overly wide at Twin Bridge Road, and narrower than expected at County Road 612 in Lovells (Table 4). About a mile downstream of Dam 4, the channel narrows (possibly due to strengthening of the banks by clay), deeper habitats occur, and a more mature riparian forest can be found. Still, relatively few natural logjams are between Dam 4 and the mouth of Big Creek-North, which delivers a considerable sand bedload. Characterizing the three branches of Big Creek-North: the West Branch is mostly sandy run habitat; the Middle Branch has more riffle-pool, gravelly habitat; and the East Branch has mostly run habitats in its upper half and gravelly, riffle-pool sequences in its lower half. Below the junction of its East and West Branches, Big Creek-North is a gravelly, riffle-pool dominated stream.

Big Creek-South

This stream forms at the confluence of its East and West branches. Both have upper reaches that are sandy runs, and lower reaches that are more gravelly. From the confluence of these branches to its mouth, Big Creek-South is mostly run habitat with sand substrate. Effects of riparian development occur in localized areas, especially along the lower couple miles of both branches, and in the lowest 2 miles of the stream near its confluence with the mainstem. Limited instream cover, riparian shading, and a lack of large woody debris all indicate the stream's young riparian forest.

Pine River

This river system consists of many small tributary streams that drain a mosaic of glacial deposits, some being relatively impermeable (Figure 3). These streams generally drain areas of young forest and agricultural lands, and are dominated by run habitat. Substrates are mostly sands, with clay and gravel in some areas. Productivity of coldwater fishes is limited by the presence of beaver dams in many streams.

Dams and Barriers

One hundred and nine dams are known to occur in the Au Sable River watershed (Table 6), with 8 on the mainstem and 101 on tributaries (Figure 14). Three dams (Salling, Old Frederic Lumber Mill, and Waszkiewicz) were recently removed. Most dams in the watershed are relatively small. Sixty-two dams have a head of 5 ft. or less (total includes small ponds lacking head information); 25 have a head of 6-10 ft; 16 have a head of 11-20 ft.; and 6 have a head >20 ft. The water storage capacity of most dams is also limited. Ninety-three dams store less than 100 acre-feet each; 7 dams store 100-999 acre-feet each; 9 dams store > 1000 acre-feet each. The 6 large hydropower dams on the lower mainstem are classified as high hazards meaning that dam failure would cause loss of life (MDEQ, Land and Water Management Division, unpublished data). All other dams in the watershed were rated as low hazard.

Thirty-five of the 109 dams in the watershed are regulated under three jurisdictions (see **Special Jurisdictions**). The State of Michigan regulates 24 dams that impound five or more acres and have a dam height greater than six feet. Legal lake levels were established at 5 dams (under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 307): Big Bradford Lake; Otsego Lake; Lake St. Helen; Au Sable Lake; and Van Etten Lake. The Federal Energy Regulatory Commission and the State of Michigan regulate six dams: Mio, Alcona, Loud, Five Channels, Cooke, and Foote. The remaining 74 dams in the watershed are subject to state regulation under Public Act 451 (see **Special Jurisdictions**).

Most dam construction occurred in two periods. Several dams were constructed around the turn of the century. Some were remnants from old logging dams that were maintained for recreational use. Six large hydropower dams (Mio, Alcona, Loud, Five Channels, Cooke, and Foote) were built between 1911 and 1924, and are now owned by Consumers Energy Company. These six hydroelectric dams alone impound over 38% of the mainstem Au Sable River. Many small dams were built in the 1960s and 1970s for recreation.

Early Records of Effects of Dams on Michigan Fishes

Early records document some effects of dams on Michigan's streams. The first dams were constructed in the mid- to late-1800s on headwater and tributary streams to aid in floating logs to sawmills located in Grayling and Oscoda. The effects of these activities have been previously discussed (see **History, Modifying Factors**), and authors such as Miller (1963) and Vincent (1962) provide further detail.

Relatively little information exists regarding the specific effects of dams on the biota of the Au Sable River. This is mostly because these effects occurred before such records were kept. However, early reports by the Michigan State Board of Fish Commissioners provide first-hand evidence that hydropower dam construction on Michigan's major rivers clearly had a dramatic effect on fish populations. Dams and fish passage abruptly arose as the major issue in Fish Commission Reports at the turn of the 20^{th} century when hydropower development began in earnest. Up to that time, reports by the Board often focused on fish stocking and developments in fish rearing techniques. In their 1905-6 Biennial Report to the Governor, the Board of Fish Commissioners quickly get to the heart of the matter stating:

> "Now that so many of our streams are stocked with food fishes, the importance of compelling the construction of fish ladders or chutes if it is feasible over the various dams that are being constructed becomes of the highest importance. Large dams for power plants are now being erected in different parts of the State from twenty to thirty or more feet in height. At the foot of these dams great quantities of fish collect

> in their desire to get up the stream. Whether such fish ladders or chutes are feasible or not may be a serious question. We recommend that this subject be given serious attention." (State Board of Fish Commissioners 1909a).

Fish passage is again the first issue discussed in the 1907-8 Biennial Report, "The construction of large dams in the streams of our state attracts attention to the question of fish ladders or chutes. If such can be constructed so as to work properly, the necessity for them is obvious" (State Board of Fish Commissioners 1909b). The importance of open connections between streams and the Great Lakes is further evidenced by the fact that fish passage remained the major issue for several years during this time. Trautman (1981) made similar observations on Ohio streams where large-bodied, valuable food fishes were blocked from spawning areas by dams. Precipitous declines in their populations occurred shortly after dam construction.

The work of the State Board of Fish Commissioners resulted in laws requiring construction of fish ladders at dams (Michigan Department of Conservation 1922). Ladders were built on all hydroelectric dams in the Au Sable River. In general, these fishways were "absolutely inefficient, [as] numerous ripe fishes gathered below the dam unable to get up" (Michigan Department of Conservation 1924). The stranded fishes became targets of illegal fishing (Michigan Department of Conservation 1922).

From 1933 to 1937, remnant runs of steelhead were trapped below Foote Dam and transferred above Alcona Dam, in an attempt to restore natural reproduction and create a sport fishery. Annual numbers of steelhead transferred during this period were 170, 94, 146, 56, and 90 (MDNR, Fish Division, unpublished records). Walleye and large numbers of suckers were also present during the steelhead run. The trap and transfer was discontinued because declining catches of steelhead at the dam did not justify the effort required for their transfer. Runs of other fishes probably showed similar declines, because they also could no longer reach spawning rapids.

Effects of Dams on River Ecosystems

Dams affect river ecosystems in a variety of ways, being especially detrimental to cold water streams (Ward and Stanford 1983). They physically affect how rivers function by altering natural transport of water, sediment, woody debris, and other organic matter. By influencing the rate at which water moves through the system they alter water quality, particularly instream productivity, dissolved oxygen levels, and temperature regimes. They influence the biota by fragmenting migration corridors previously used by aquatic organisms, eliminating rare high-gradient habitats, and providing altered habitats for organisms that might otherwise have been unsuited to riverine environments. The following discussion will touch on many of these aspects in regards to the Au Sable River. Many examples will focus on the 6 major hydropower dams on the lower mainstem for which there are the most data.

Reduction of current velocity in a river by dams disrupts normal processes of sediment transport. Sediment that was being carried downstream by the river is deposited instead at the upstream end of the impoundment. Below the dam, the river is energetically out of equilibrium because it is not doing its normal work of carrying a bedload of sediment. It expends this excess energy by picking up an unusually large amount of sediment in reaches immediately below the dam and transporting it. This erosion produces channels below dams that are often unusually narrow or wide, depending on the whether the banks or bed are more erodible. Dams located near river mouths, such as those in the Au Sable River, prevent the sediment deposition needed to maintain river delta and marsh habitats. Deltaic sandbars and marshes are mentioned in historical accounts of many Michigan rivers (see **History**, Zorn and Seelbach 1992; Hay-Chmielewski et al. 1995; Rozich 1998). This suggests that these habitats were much more common before European settlement, and played a more dominant role in Michigan's aquatic ecosystems than they now do.

Large woody debris plays many important roles in river ecosystems, and in the past, had a more prominent role in the ecology of rivers and their receiving waters (see **History**; Keller and Swanson 1979; Zorn and Seelbach 1992; Maser and Sedell 1994; Large and Petts 1994). For example, large woody debris in streams provides: a source of nutrients for production; stable substrate for plant growth and invertebrate production; cover for fishes; and increased diversity in depth, velocity, substrate, and lighting conditions of stream channel habitats. Dams have largely ended the downstream transport of large woody debris from the Lower Au Sable River to Lake Huron. Large woody debris typically gets waterlogged and sinks in the slack water habitat created by reservoirs. The little that makes it to the dam accumulates on trash racks and is removed by dam operators. Incoming large woody debris is now not being passed downstream at Consumers Energy dams (K. Kruger, MDNR, Fisheries Division, personal communication).

Dams can alter natural flow regimes of streams, causing unnatural changes in erosion and channel morphology. Former peaking operations at hydropower dams on the Au Sable River caused extreme flood and drought conditions on a daily basis. In 1924, Hubbs and Langlois noted that in the river below Mio dam there was no flow on "most nights" and water levels fluctuated about 6 feet with opening and closing of the dam (Fisheries Division records). Floods cause excessive erosion and sediment transport, typically down cutting the channel immediately downstream of the dam. MacDonald (1942) reported that farmers sued Consumers Power Company for causing erosion of their lands, and that the company purchased riparian lands to prevent such "further incidents". Obviously, daily floods and droughts are stressful to aquatic organisms. Mio and Foote dams have been operated at run-of-river (for the most part) since 1966 (Mio) and 1994 (Foote), and recent peaking operations at other hydropower dams on the river have been somewhat less frequent and dramatic.

Maintenance of inland lake levels by abruptly installing or removing boards at lake-level control structures can also produce harmful flood and drought conditions. For example, rapid drawdowns of Lake St. Helen were strongly linked to poor reproductive success of brown trout in the South Branch Au Sable River (Nuhfer et al. 1994). The issue of flow fluctuations below lake-level control structures is or has been a concern on other lakes too, including Otsego and Van Etten lakes. The simple existence of a dam necessitates periodic maintenance and manipulation of flows, with effects that can range from minor to catastrophic.

Dams used to maintain constant water levels of lakes eliminate the naturally-occurring, slow changes in water levels that happen between seasons and years. This leads to losses in riparian wetland habitats that need wet and dry periods. Constant water levels along lake shorelines and at lake outlets prevent natural drying cycles, leading to accumulations of un-decomposed organic matter. Such stagnation reduces the quality of shoreline wetlands as spawning areas and habitats for fishes and invertebrates. In addition, maintaining constant lake levels and shoreline conditions may encourage further (or more intensive) shoreline development.

Temperature elevation is a major effect that dams have on cold water streams, such as the Au Sable River. Excessive temperatures raise metabolic rates of coldwater species, resulting in less efficient growth, fewer fat reserves, and reduced survival (Magnuson et al. 1979; Brett 1979; Moyle and Cech 1982; Meisner et al. 1987). Dams increase summer stream temperatures by slowing water down and spreading it out in a pond. In other words, a greater surface area of water is exposed to the sun's radiation for a longer period of time. The presence of a pond on a cold water stream increases summer temperatures and reduces daily fluctuations in temperature, producing a stable, elevated thermal regime that is stressful to coldwater-adapted organisms (Figure 15). Ironically, high-gradient reaches on Michigan streams are often areas of significant groundwater accrual (and cooling) because the channel repeatedly intercepts the water table (Zorn et al. 1997). Coopes et al. (1974) estimated that mainstem impoundment in the Grayling area (Salling and Grayling dams) raised maximum summer temperatures in the stream by 4-6 ºF, and recommended removal or these dams to restore cold water stream habitat. Removal of Salling Dam restored several miles of cold water stream habitat. Average increases in maximum July temperatures through the reach impounded by Salling Dam declined from about 6 ºF during the dam's existence (Coopes et al. 1974) to less than 2 ºF after its removal in 1991 (MDNR, Fisheries Division, unpublished data).

Effects of large dams on the thermal regime of the lower mainstem are considerable. Comparing stream temperatures for July 1990, the lower mainstem above Mio Pond (Figure 15) had a mean temperature of 64.5 ºF and a weekly temperature range of 4.3 ºF. Below Mio Pond the mean increased to 67.8 ºF and the range declined to 1.9 ºF. Due to less nighttime cooling in the pond, stream temperatures downstream of the dam were below 63°F (the upper limit for brown trout growth; Elliott 1994) for only 0.2 hours in July 1990. In contrast, stream temperatures upstream of Mio Pond were below 63 F for 139.4 hours in July 1990 (MDNR, Fisheries Division, unpublished data). Further downstream, in the riverine reach between the Mio Dam discharge and Alcona Pond, the river cools some (due to groundwater accrual) and temperature fluctuations increase. Similar warming and reduced temperature fluctuations occur as the river flows through Alcona Pond; July mean temperatures increase from 66.9 ºF to 69.9 ºF and fluctuations decline from 6.7 ºF to 1.9 ºF. The deleterious effect of this warming is shown by declines in coldwater species that live below each impoundment (see **Biological Communities**). Temperatures cool and fluctuations return in the short riverine reach below Alcona Dam, before the mainstem is influenced by Loud Pond. From here downstream, back to back impoundments maintain warm, stable summer temperatures (Figure 15). Based on rates at which free-flowing reaches of the lower mainstem warm, we estimated that removal of dams here would result in a 2-3° F reduction in mean July temperatures and make roughly 60 more miles of the lower mainstem capable of supporting self-sustaining trout populations (MDNR, Fisheries Division, unpublished data). Such a large, spring-fed, cold water river would indeed be an unusual and unique resource.

All large hydroelectric dams on the lower mainstem draw and release water from the upper two thirds of the water column. As a result, downstream reaches are warmed during the summer. Summer temperature profiles of Alcona and Mio ponds show 50-60 ºF water below the thermocline (MDNR, Fisheries Division, unpublished data). Spilling this cold water could help restore the value of downstream riverine reaches for reproduction and growth of coldwater fishes, such as trout and salmon. FERC (1994) estimated the duration of cold water (<68ºF) flows that could be released below each of the Consumers Energy dams. They concluded that releases of short-term temperature regime enhancement flows were feasible at the Mio and Alcona projects, but not at the other projects.

The greater surface areas and higher temperatures caused by dams increase evaporation from a river. Average pan evaporation in the Au Sable River basin is about six inches per month in midsummer based on data provided by Eichenlaub (1990). Assuming that evaporation from a reservoir is about 75% of the pan evaporation, this implies loss of 0.006 cfs of streamflow per surface acre of water impounded. On the average the 10,380 acres of impoundments on the Au Sable River may reduce midsummer streamflow as much as 63 cfs or five percent of July discharge, which is comparable to the entire flow at the Grayling gauge station (67.5 cfs, mean July discharge).

Fragmentation of riverine habitats and their subsequent isolation from the Great Lakes are major effects of dams. Life history accounts (e.g. Scott and Crossman 1973; Trautman 1981; Becker 1983) describe migrations for 61 of 114 species of fishes in the Great Lakes region. Fish use distinctly different habitats throughout their lives, and movement between them can range from a few feet to 100s of miles. For example, Clapp (1988) and Hudson (1993) found that individual brown trout in the Au Sable River traveled considerable distances, some over 20 miles, within the system to forage, spawn, and find refuge from adverse summer or winter conditions. Likewise, many stream-dwelling aquatic insects drift downstream as larvae seeking desirable habitats and fly back upstream to reproduce. The presence of a reservoir (i.e. very low velocity habitat) hinders downstream drift. In addition, the long reaches of impounded habitat created by dams may act as barriers to adult insects that cannot fly or can only fly short distances upstream to riverine habitats. Maximum productivity of a river system is obtained when all species can freely migrate throughout the system, taking advantage of the best habitats (spawning, growth, and refuge) as needed throughout their lives (Figure 16). For example, many large-bodies fishes that grow in Lake Huron need cold water riffles and rapids for spawning. Such fishes include lake whitefish, round whitefish, lake herring, lake trout, rainbow trout (steelhead), brown trout, chinook salmon, coho salmon, burbot, walleye, lake sturgeon, greater redhorse, river redhorse, silver redhorse, golden redhorse, longnose sucker, and white sucker. Dams have reduced productivity of the Au Sable River by preventing these fishes from accessing cold water rapids for spawning. In addition to hatching and growing up, the fry of migratory fishes would have provided an important source of food for resident stream fishes, further increasing productivity of these habitats (Bilby et al. 1998). Also, fishes above dams cannot migrate downstream to take advantage of seasonally available habitat or food resources below dams. In summary, habitat fragmentation results in poorer condition of individual fishes, reduced (remnant) populations of species, higher extinction rates, limited recolonization by migrants, lower diversity, and lower productivity.

Entrainment and mortality of fishes in turbines of hydropower dams on the Lower Au Sable River is significant. In 1991, it was estimated that the six hydropower operations on the river entrained over one million fish and killed 230,487 fish (Table 7). Some of the most frequently killed fish were sport fishes, with considerable mortalities of walleye, smallmouth bass, rock bass, and yellow perch. Foote, Mio, and Alcona dams killed the most fish on a biomass basis, while Cooke, Five Channels, and Foote dams killed the most fish based on numbers. The economic value of fish killed annually by the Au Sable River hydroelectric dams is impressive. In 1991 alone, the estimated value of fish killed by the six dams was between $398,712 and $2,483,428 (Table 7). Estimated values vary due to the use of two different methods for assessing value to fish kills. Foote Dam caused the greatest damage on an economic basis, with Five Channels, Cooke, and Mio dams also inflicting substantial economic losses. The 1994 Settlement Agreement (Appendix 1) provides for mitigation of these losses. Monetary restitution will decrease as fish protection devices are installed and fish mortalities decrease.

Hydropower dams on the Au Sable River change rare, high-gradient reaches of the river into lentic habitats that are often marginally productive when compared to true lakes. This is especially true of the six impoundments on the lower mainstem which have very low water retention times; none have retention times greater than 12 days (FERC 1994). Water flushes through these ponds so rapidly that characteristics typical of natural lakes, such as high plankton production and thermal stratification, do not develop to much extent. As a result, these ponds may not be able to support large populations of valuable lentic sport fishes (e.g. largemouth bass, smallmouth bass, walleye, yellow perch, sunfishes, and black crappie), and have somewhat limited sport fishery management potential (see **Biological Communities** and **Fishery Management**). This is supported by the preponderance of fishes typical of cool, backwater environments noted in fisheries surveys. Such species include bowfin, black bullhead, white sucker, and northern pike. In addition, populations of many invading aquatic species that occur in some ponds, such as zebra mussels, Eurasian milfoil, and common carp, require lentic habitats to thrive. Without the ponds, the Au Sable River would be too cold, too fast, and too unproductive to allow populations of these species to reach high (or even moderate) levels. (see **Biological Communities**).

The lost productivity of rare, high-gradient, currently impounded reaches of the lower mainstem and its tributaries would undoubtedly be phenomenal. We estimated the potential production of chinook salmon and rainbow trout (steelhead) smolts, and lake sturgeon in the Au Sable River from mid dam to the river mouth. Gary Whelan (MDNR, Fisheries Division, unpublished data) developed relationships between stream gradient and fish population size from published studies (e.g. Carl 1982; Thuemler 1985; Seelbach 1986; Auer 1995; Auer 1996) and unpublished data (R. O'Neal, MDNR, Fisheries Division, unpublished data) from streams in Michigan and other Great Lakes states. We used these relations to make predictions of smolt production and adult fish runs in impounded reaches after dam removal, and in riverine reaches between dams. We estimated that existing riverine reaches between Mio Dam and Loud Pond alone could annually produce 1,600,600 chinook salmon smolts and 517,930 steelhead smolts, and support an adult run of 14,440 lake sturgeon (Table 8). If the five most downstream dams on the lower mainstem were removed, the restored riverine reaches could annually produce an additional 1,107,700 chinook salmon smolts and 358,435 steelhead smolts, and support an adult run 19,760 lake sturgeon.

We made similar estimates using data from Rutherford et al. (1997) who worked on the Manistee River below Tippy Dam. They estimated abundance of chinook salmon smolts in June and young-of-year steelhead in September as 887,424 and 24,864 fish per mile over 4.3 miles of a 4.65 ft/mi reach of the Manistee River. Using their production rates, we estimated that existing riverine stretches of the lower mainstem having gradients >4.65 ft/mi, could produce 10+ million June chinook salmon smolts and over 290,000 September young-of-year steelhead. Without the five most downstream lower mainstem dams, an additional 9+ million June chinook smolts and 258,586 September steelhead young-of-year could be produced (Table 8). Actual abundance of these species in the Au Sable River would vary depending on differences in stream conditions, especially temperature and current velocity. Still, these estimates provide a picture of the incredibly-high potential productivity of an unfragmented Au Sable River, and suggest that fish passage and dam removal would greatly contribute to rehabilitation of the Au Sable River ecosystem and its relation with Lake Huron. However, dam removal could also provide some undesirable species (e.g. sea lamprey) with access to the river, so management would be needed to maintain a desirable fish community.

Negotiations between Consumers Energy and resource agencies resulted in a proposed Settlement Agreement designed to provide mitigation for effects of many hydroelectric dams on the Au Sable River. The Offer of Settlement was submitted to the FERC along with the new license applications and 40-year licenses were issued in July 1994. See **Special Jurisdictions** for further details, and Appendix 1 for a copy of the Settlement Agreement, which was a basis for the issued licenses.

Smaller Dams in the Watershed

All dams, regardless of size, show many of the above effects, though often not as dramatically. Consequently, we discourage construction of new dams, support dam removal when possible, and favor the installation of fish passage structures at existing dams.

Eight dams are owned by the State of Michigan. Four of these dams, Big Creek (Crawford County), Old Frederic Lumber Mill, Robinson Creek Flooding, and East Branch (Oscoda County) are on streams classified as trout streams. These dams are fairly small, having 2-10 ft of head, but have the same effects as larger dams (particularly temperature elevation). Three state-owned dams (Sandhill Lake, Conner's Marsh, Beaver Lake Flooding) are on warm-cool streams and have less of a thermal effect, but do block fish movement, alter water quality, and prevent natural downstream transport of sediment and woody debris. Investigations should be made into all these dams regarding their usefulness or potential for removal. Dams at Sandhill Lake and the Old Frederic Lumber Mill are essentially gone and no longer block fish movement and normal stream processes. The Mio DNR walleye pond is used by MDNR, Fisheries Division for rearing walleye fingerlings for stocking and the dam is on a small warmwater tributary to Mio Pond.

The Grayling Dam in the city of Grayling degrades the quality of several miles of the upper mainstem. The dam is affecting a reach of the mainstem that is classified as top quality trout water, is designated as a Blue Ribbon trout stream, and is a State Natural River. The dam is elevating July maximum temperatures by an estimated 4-6 ºF, blocking fish movement, and preventing natural downstream transport of sediment and woody debris. Ownership of the dam is in question. Coopes et al. (1974) recommended that this dam be removed due to its effects on the river.

There are 102 dams on tributaries of the Au Sable River. Aside from the few tributary dams discussed above, the specific effects of most of these dams have not been evaluated. In addition, perched culverts at road-stream crossings can present barriers to fish movement. Perched culverts occur when erosion on the downstream side of the culvert proceeds to the point where a waterfall exists between the culvert outlet and downstream waters. Surveys are needed to identify tributary dams and road-stream crossings having detrimental effects.

Water Quality

General Water Quality, Point and Nonpoint Source Issues

Water quality in the Au Sable River is generally good, owing primarily to the limited amount of development within the basin (see **Soils and land use patterns**). Historic data (Tables 9 and 10) and recent data (Table 11) on water quality characteristics of the mainstem and its major tributaries are near what is considered normal for Michigan streams by Michigan Department of Environmental Quality (MDEQ), Surface Water Quality Division (SWQD) (Table 12).

Nutrient enrichment by municipalities was an issue in the early 1970s, particularly in the mainstem below Grayling and the South Branch Au Sable River below Roscommon (see reports in Appendix 2). These problems were resolved through enactment of stricter water quality standards and improvements made to wastewater treatment facilities in Grayling (1971) and Roscommon (1974). Notable reductions in organic enrichment followed and biological productivity in these areas declined accordingly. Reduced biological productivity in reaches downstream of these towns appeared to reduce brown trout growth (Merron 1982), and may partly explain changes in abundance of the species over time (see **Biological Communities**). Recent water quality data (Table 11) suggest that nutrient levels (e.g. total phosphorus) in much of the river system may be 2-3 times lower than in the past (Tables 9 and 10). To better quantify the extent of these changes, water quality (and nutrient) data are needed at sites where historic measurements were made.

Point source discharges into the system are regulated under authority granted by the Clean Water Act (see **Special Jurisdictions**). These sources are regulated through National Pollution Discharge Elimination System (NPDES) permits that are issued and administered by the MDEQ, SWQD. There are 13 permits issued for the watershed for wastewater treatment, industrial discharge, hydropower operation, and combined sewer overflows (Table 13). NPDES permitted facilities have generally maintained consistent compliance with permit requirements. Occasional variances from permit requirements have occurred, but they have not adversely affected receiving waters (R. Shoemaker, MDEQ, SWQD, personal communication).

Groundwater quality is generally excellent throughout the watershed, although a number of localized areas have been adversely affected by past and present human activities (Table 14). Sources of contamination include leaks from underground storage tanks, landfills (civilian and military), wastewater treatment facilities, and oil and gas extraction. Nonpoint sources of chemicals to streams include runoff of agricultural or lawn chemicals, effluents from leaking septic tanks, and runoff of salt brines applied to roads for dust control or to melt snow. Use of salt brines in particular is a concern due to a lack of information regarding their effects on the river. County road commissions develop brine management plans, and plan implementation happens with little to no state-level oversight (R. Shoemaker, MDEQ, SWQD, personal communication). The effects of these non-point sources on the river system may be worthy of study.

A long-standing concern relates to the intensive use of lands in the watersheds of the East and North branches of the Au Sable River for military training. Explosion of various munitions and improper disposal of excess propellants have released chemicals into the environment at the Camp Grayling Michigan Army National Guard Training Site. The Michigan Department of Military Affairs recently completed an environmental investigation of the Range 40 artillery range and air-to-ground complex (Hunt and Huntington 1998). They found that surface waters (lakes and streams), lake and stream sediments, groundwater, fisheries, and air quality were not adversely affected by explosive-related chemicals. However, low levels of metals were detected in soils, lake and stream sediments, and groundwater. Propellant disposal practices were stopped in 1993 and all contaminated propellant disposal sites have been cleaned up to MDEQ standards. In fall 1999, a 5-year monitoring plan was initiated to assess potential affects to surface waters, groundwater, and sediments surrounding the Range 40 complex (L. Jacobs, Department of Military Affairs, personal communication).

Much of the Au Sable River system is affected by an excessive sand sediment bedload, which is detrimental to many aquatic species that need clean rocky substrates (Alexander and Hansen 1986). Sources of these sediments are eroding stream banks, road crossings, access points, commercial canoeing, and historic land use practices. Sedimentation is a major concern in regards to oil and gas development activities (see **Soils and Land Use Patterns**). Inventories of sedimentation sources have been completed for much of the watershed and many problem sites have been addressed (see **Soils and Land Use Patterns**). In some areas, blowouts of residential water-wells improperly drilled into artesian aquifers can be a significant source of sediment to streams. In 1996, two serious incidences of well blowouts in the Pine River drainage added both sand and suspended clay particles to the stream. These resulted from improper installation and maintenance of artesian wells (R. Shoemaker, MDEQ, SWQD, personal communication). Areas along the East and West branches of the Pine River and Van Etten Creek are the only areas in the watershed where sedimentation resulting from agricultural activities is a major concern. Problems are from livestock accessing streams and inadequate vegetative buffer strips along streams.

Stream Classification

Michigan Department of Natural Resources (MDNR), Fisheries Division, classified streams throughout state in 1967. The classification system is based on stream temperature and habitat quality, stream size, and riparian zone development (Figure 17). It was developed for use in: establishing water quality standards for Michigan streams; assessing stream recreation values; designating "wild and scenic" rivers; administering stream and stream frontage improvement and preservation; identifying dam and impoundment problems; administering fishing and boating access; and targeting fishing regulations, research planning, stream land acquisition, and potamodromous fisheries. This classification remains relatively accurate for the Au Sable River and is useful in considering water quality with respect to fishery uses. Top quality and second quality cold water streams are “designated trout streams” (Figure 17). The river’s spectacular groundwater resources are evident in that 82% of the river system consists of designated trout streams. The remaining 18% is classified as "warm" water with nearly half of that attributable to the six Consumers Energy impoundments.

Temperature and Dissolved Oxygen Issues

Summer temperature elevation of cold water streams is detrimental to coldwater-adapted aquatic organisms, and in this respect is considered thermal pollution. Excessive temperatures raise metabolic rates of coldwater species, the effects of which may be seen in less efficient growth, fewer fat reserves, and reduced survival, all increasing the chances of local extinction (Magnuson et al. 1979; Brett 1979; Moyle and Cech 1982; Meisner et al. 1987). A variety of activities can cause temperature elevation including: spilling of surface waters at dams; activities which make the stream channel excessively wide or shallow; loss of riparian shading; discharge of warmed effluents from industries and municipalities; and actions such as urban development and paving which reduce infiltration of precipitation to the water table and increase surface runoff.

All dams in the watershed discharge surface waters and thus contribute to elevation of stream temperatures. The thermal effects of Consumers Energy dams have been addressed in the Settlement Agreement (Appendix 1). These dams increase summer temperatures in reaches of the river that receive considerable groundwater, thus elevating daytime temperatures. The large size of the ponds reduces the daily variation in river temperatures, and prevents nighttime cooling (see **Dams and Barriers**). The FERC licenses for the projects state that monthly average temperatures downstream of each project for July, August, September, and October should not exceed 68, 68, 63, and 56 ^{o}F. Provisional data suggests these values were exceeded below dams in 1998 as follows: July- Mio, Alcona, Loud, Five Channels, Cooke, and Foote dams; August- Alcona, Loud, Five Channels, Cooke, and Foote dams; September- Alcona, Loud, Five Channels, Cooke, and Foote dams; and October- Cooke and Foote dams (D. Battige, Consumers Energy, unpublished provisional data). The Settlement Agreement also states that no project should increase the average monthly temperature of the river by more than 2^{o}F. Greater than 2^{o}F warming happened in 1998 as follows: June- Foote Dam; July- Mio and Alcona dams; August- Mio and Alcona dams; September- Mio and Alcona dams; October- Mio, Alcona, and Cooke dams; October- Cooke Dam; and November- Cooke Dam (D. Battige, Consumers Energy, unpublished provisional data). Continued monitoring is needed to document these violations.

Other dams throughout the watershed also need to be examined for their effects on downstream water quality and temperatures. The Grayling dam is elevating summer temperatures of premier trout waters on the mainstem by an estimated 4-6 ^{o}F (Coopes et al. 1974). The effect of this dam needs to be documented. Removal of Salling Dam in 1991 restored several miles of Blue Ribbon trout waters on the mainstem (see **Dams and Barriers**). Thermal effects of other dams on downstream temperatures should be documented to identify where they are greatest.

Adequate levels of dissolved oxygen are also essential for aquatic life to thrive (Brett 1979; Moyle and Cech 1982). Levels are generally adequate in riverine reaches due to turbulent flows, but problems can occur when excessive nutrients enter the system or where dams alter normal streamflow patterns. Excessive nutrient inflows by municipalities created such a problem in portions of the watershed (e.g. mainstem below Grayling and South Branch Au Sable River below Roscommon) before passage of the Clean Water Act. Water quality problems now exist in portions of the Pine River system due to livestock accessing streams (R. Shoemaker, MDEQ, SWQD, personal communication).

With the exception of large dams on the lower mainstem, the effect of dams on downstream dissolved oxygen levels has not been documented in the watershed and a survey is needed. The Settlement Agreement with Consumers Energy identified 7 mg/l as the minimum dissolved oxygen level that must be maintained below their dams on the lower mainstem (Appendix 1). Measurements in 1998 indicated that these levels were not maintained as follows: May- Alcona, Loud, and Five Channels dams; June- Alcona, Loud, and Five Channels dams; July- Mio, Alcona, Loud, Five Channels, Cooke, and Foote dams; August- Mio, Alcona, Loud, Five Channels, Cooke, and Foote dams; September- Alcona, Loud, and Five Channels dams; and October- Loud Dam (D. Battige, Consumers Energy, unpublished data). Minimum dissolved oxygen levels in riverine reaches above Mio and Alcona ponds were <7 mg/l during 5 of 7 months where dissolved oxygen levels <7 mg/l were measured below these dams. Continued monitoring is needed to determine how often minimum dissolved oxygen standards are not met.

Fish Consumption Advisories

Mercury consumption advisories have been issued statewide for piscivorous (fish-eating) fishes common to lakes and reservoirs in the state. Mercury is highly toxic to aquatic organisms and very persistent in the environment. The methyl form of mercury is most common in fish, and bio-concentration factors from water to fish range between 1,800 and 85,000 (O'Neal 1997). Long-term ingestion of mercury-contaminated fish can produce symptoms such as numbness of extremities, tremors, spasms, personality and behavior changes, difficulty in walking, deafness, blindness, and death. Mercury levels in Michigan fish tend to be higher in larger, fattier fishes of inland lakes than fishes in streams (Michigan Department of Community Health 1998).

Mercury can enter water bodies from point-source discharges, nonpoint source runoff, or atmospheric deposition. The Michigan Department of Natural Resources Wastewater Report for 1993 listed one industrial user of mercury in the Au Sable Basin (Sheer Motors, Grayling), and their discharge was less than 1 pound of mercury per year (C. Hull, MDEQ, SWQD, personal communication). Total mercury discharge to Michigan's surface or groundwaters in 1991 was between 200-1800 pounds (Anonymous 1996). Atmospheric emissions of mercury in Michigan range from 8,400 to 10,400 pounds per year (Anonymous 1996). Most emissions are deposited within 622 miles of the source. Electric utility coal combustion (41%), municipal waste incineration (28%), hospital waste incineration (9.4%), and industrial and commercial coal combustion (6.5%) compose the bulk of air emissions of mercury in Michigan. Disposal of mercury in the municipal and commercial solid waste stream was estimated at 3,750-3,800 pounds in 1985 (Anonymous 1996). Sources include: lamp manufacturing and breakage; electrical switches; batteries; thermostats; lab use; and dental amalgam preparation.

Fish consumption advisories due to high PCB (polychlorinated biphenyl) levels exist for the following Lake Huron fishes: brown trout, burbot, chinook salmon, coho salmon, lake trout, lake whitefish, rainbow trout, and carp (Michigan Department of Community Health 1998). Advisories due to PCBs exist for carp in the Au Sable River at Oscoda, and for carp, walleye, and channel catfish in Van Etten Lake. PCBs are relatively insoluble, persistent, readily bond to organic matter, and have a high bioaccumulation potential (O'Neal 1997). They are commonly detected in the tissue and eggs of fish-eating birds, and have been shown in studies of laboratory animals to suppress the immune system and damage the liver, stomach, kidneys, and thyroid.

PCBs were once widely used in various products, including electrical transformers and capacitors, carbonless copy paper, plasticizers in plastic and rubber products, and hydraulic fluids (Science Applications International Corporation 1993). Their high stability contributed to their commercial usefulness and long-term, detrimental environmental and health effects (O'Neal 1997). In 1982, the United States Environmental Protection Agency (EPA) restricted their use to electrical equipment, though use of PCB transformers and large capacitors could continue in limited access areas until they were worn out. The Michigan Department of Natural Resources Wastewater Report for 1993 listed no industrial users of PCBs in the Au Sable River basin (C. Hull, MDEQ, SWQD, personal communication).

PCB levels in lake trout in Lake Huron are roughly half those of lake trout in Lakes Michigan and Ontario, and have declined somewhat since the late 1970s and early 1980s (De Vault et al. 1996; Figure 18). PCB concentrations have remained fairly level since 1986. Most (63%) of the PCBs enter the Lake Huron basin via atmospheric deposition (United States Environmental Protection Agency 1997). Studies using caged channel catfish to monitor uptake of PCBs in different streams showed little PCB uptake for the Au Sable River in 1991 and no detectable uptake in 1996 (Figure 19). PCB levels in brown trout collected from the North Branch Au Sable River and Big Creek-South were well below the trigger level for a fish consumption advisory (2.0 mg/kg). In fact, PCBs could not be detected in 14 of 15 fish sampled (B. Day, MDEQ, SWQD, unpublished data). Analyses of chinook salmon collected below Foote Dam since 1983 have consistently shown average total PCB concentrations <1.50 mg/kg (B. Day, MDEQ, SWQD, unpublished data). Concentrations in rainbow trout samples from 1991-3 were < 0.6 mg/kg.

Fish advisories for chlordane contamination have been issued for lake trout in Lake Huron. Chlordane was used primarily as an insecticide before being banned by the United States EPA in 1988. It is highly persistent in aquatic environments, having a half-life of 3.3 years, and readily moves up the food chain, with bioaccumulation factors ranging from 7,240 to 20,000 (O'Neal 1997). It is also readily transported through the atmosphere. Chlordane, when administered orally, has been shown to cause liver carcinomas in rats and mice, and chronic exposure caused liver disease in rats, mice, and dogs (O'Neal 1997). Chlordane can also cause blood disorders such as anemia. Chlordane levels in whole lake trout from Lake Huron are intermediate relative to those in other Great Lakes, and have been fairly constant between 1986 and 1992 (Figure 20).

Fish advisories for dioxin contamination have also been issued for lake trout in Lake Huron. Dioxins form as unwanted impurities during the manufacture of other organic compounds, and can be generated as a byproduct of paper and pulp mill processes that use chlorine (O'Neal 1997). TCCD (2,3,7,8 tetrachlorodibenzo-p-dioxin), the most toxic and understood type of dioxin, is classified by the United States EPA as a probable human carcinogen. In studies using laboratory animals, it has been shown to cause adverse reproductive effects, including reduced fertility, spontaneous abortion, and birth defects (O'Neal 1997). The Michigan Department of Natural Resources Wastewater Report for 1993 listed no industrial users of dioxins in the Au Sable River basin (C. Hull, MDEQ, SWQD, personal communication). Dioxins presumably enter Lake Huron from other sources.

Special Jurisdictions

Many Federal and State rules are associated with protection of the Au Sable River watershed. The most pertinent ones are highlighted.

State and Federally Designated River Segments

Twenty-three miles of the Au Sable River, from approximately 1 mile downstream of Mio Pond to the upstream end of Alcona Pond, are designated as a Federal Wild and Scenic River under the National Wild and Scenic Rivers Act (Public Law 90-542). The intent of the Federal Wild and Scenic Rivers program is to preserve certain selected rivers, which possess outstanding geologic, fish and wildlife, historic, cultural, or other values. Standards and guidelines that direct management activities within the designated area are intended to keep the river in a free-flowing condition for the benefit and enjoyment of present and future generations. This section of river has a Management Plan under the authority of the U.S. Forest Service.

Ninety-eight miles of the mainstem, from the confluence of Kolke and Bradford Creek to Loud Dam, and 251 miles on 29 tributaries are designated as State Natural Rivers (Table 15 and Figure 21). These segments were designated under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 305. A river segment may be designated as a "natural river" for the purpose of preserving and enhancing its ecological and recreational value. Detailed guidelines for management and zoning regulations are discussed in the Au Sable River Natural River Plan (Anonymous 1987). The rules regulate the type and density of development within the riparian corridor and include various zoning restrictions on lot size, building set backs, riparian vegetation management, and commercial use. The Natural Rivers district extends to 400 feet back from the ordinary high water mark. Zoning requirements prevent building within 200 feet of the stream edge on the mainstem, South, and North branches of the Au Sable River and 100 feet on tributaries, and require a minimum lot width of 200 feet. All septic systems must be at least 150 feet from the stream edge. A 75-foot natural vegetation strip (green belt) is required on the mainstem, South, and North branches of the Au Sable River, and 50-foot strip is required on tributaries. A natural vegetation strip of 150 feet is required for all public land bordering designated segments. These zoning standards are administered by local governments at county and township levels. The State of Michigan administers these standards if local governments choose not to.

Water quality regulations

Michigan administers the Federal Water Pollution Control Act (Federal Clean Water Act, Section 404) under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 31. Under Part 31, the State has the authority to protect and conserve the Michigan's water resources and to control pollution of surface or underground waters.

Contaminated Sites

The Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 201, Environmental Response, gives the state the authority to identify sites of environmental contamination; to request liable parties to take response action for site cleanup; and to prioritize contaminated sites for state funded clean up. As of April 1998, 98 sites have been identified in the Au Sable River watershed (Table 14).

Dredge and Fill Activities

The federal government has the authority to regulate dredge and fill activities in the mainstem from Foote Dam to the mouth under the Clean Water Act; Section 404(b)(1) for waters included in Section 10 of the federal rules. These guidelines are published in the Federal Register, Volume 45, Number 249, Part 230.

The State of Michigan has authority to regulate development activities affecting lakes, streams, or wetlands under the Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, parts 301 and 303. Part 301, Inland Lakes and Streams, gives the state the authority to regulate certain activities including: dredge or fill of bottom lands; construction, enlargement or removal of structures on bottomlands; marina construction and operation; creation, enlargement or diminishing an inland lake or stream; construction or dredging in wetlands within 500 feet of the ordinary high-water mark of an existing inland lake or stream; and connecting any natural or artificial waterway with an existing body of water. Part 303, Wetland Protection, gives the state the authority to regulate certain activities within wetlands including: placement of fill materials into a wetland; dredging or removal of soils from a wetland; construction within a wetland; or draining surface water from a wetland. Many of these activities are also subject to Natural River zoning ordinances and rules.

Inland Lake Levels and Dams Regulated under Dam State Dam Safety Standards

Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 307, outlines the process involved in establishing a legal inland lake level. After going through the process, the circuit court where the lake is located establishes a legal lake level that takes social, economic, and environmental aspects into consideration. Legal lake levels have been established at 5 lakes within the watershed: Big Bradford Lake; Otsego Lake; Lake St. Helen; Au Sable Lake; and Van Etten Lake.

Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, gives the State of Michigan the authority to regulate dam construction, alteration or removal; water quality conditions associated with dams; and operations of dams, including those dams that are regulated under the Federal Powers Act, chapter 41. Federal regulations supercede state regulations on federally regulated dams in some instances. Part 315 (Dam Safety) of Public Act 451 specifically regulates dams impounding five or more acres and having a dam height greater than six feet. Twenty-four dams in the Au Sable River watershed are regulated under this act. The State of Michigan also requires that dam owners obtain state permits if operating outside of permitted conditions.

Federally Regulated Dams

Six hydroelectric dams on the mainstem Au Sable River were relicensed, by the Federal Energy Regulatory Commission (FERC), for a 40-year period beginning in 1994. FERC provided for review and consideration of natural resources issues as part of the relicensing procedure. Resource agencies (Michigan Department of Natural Resources, United States Department of Agriculture Forest Service, United States Department of Interior Fish and Wildlife Service, United States Department of Interior National Park Service, and Michigan State Historic Preservation Officer), the Michigan Hydropower Relicensing Coalition, and Consumers Energy worked for several years to study and evaluate environmental effects of these dams on the Au Sable River system. These negotiations resulted in a Settlement Agreement between Consumers Energy and resource agencies that was designed to provide mitigation for many effects of hydroelectric dams on the river system. The Offer of Settlement was submitted to the FERC along with the new license applications and licenses were issued in July 1994. Most components of the proposed Settlement Agreement were incorporated as provisions of the new licenses.

The final Settlement Agreement for Mio, Alcona, Loud, Five Channels, Cooke, and Foote projects on the Au Sable River is included in Appendix 1. The Settlement Agreement provided resolution on: management of project lands; protection for fish migrating downstream through projects; water quality standards and monitoring (water temperatures, dissolved oxygen, contaminants, sediment); streamflow monitoring; historical and archeological resources; fish passage structures; project boundaries; dam retirement studies and trust fund; coordination and implementation of Settlement Agreement; communication procedures between resource agencies and Consumers Energy; dispute resolution; liquidated damages; soil erosion control; and project operation procedures for Mio, Alcona, Loud, Five Channels, Cooke, and Foote dams. Resulting FERC operating licenses for the dams incorporated these issues, with the exception of liquidated damages.

Major Public and Private Landowners

Sixty-five percent of the watershed is owned by four entities. Thirty-six percent of the watershed is in the State of Michigan's Au Sable State Forest, and 30% is in United States Forest Service's Huron-Manistee National Forest (MDNR Spatial Information Resource Center, unpublished data). All management activities in the Au Sable State Forest, including timber production, recreation, and land use, are planned by MDNR Forest Management Division through a process that allows for comment from various agencies and the public. The State of Michigan Military Board (Camp

Grayling Michigan Army National Guard) leases portions of State Forest land for use in training. They have developed a draft land management plan to document their existing and proposed plans to protect natural resources and their agreements to work cooperatively with other agencies and organizations on ecosystem-based management (L. Jacobs, Michigan Department of Military Affairs, personal communication). The intent of the USFS Huron-Manistee National Forest's Land and Resource Management Plan (United States Department of Agriculture, Forest Service 1986) is to provide direction for multiple use management and the sustained yield of goods and services from national forest system lands in an environmentally sound manner. For information regarding the USFS plan contact the United States Forest Service, 1755 S. Mitchell Road, Cadillac, MI 49601. One percent of the watershed is owned by Consumers Energy. Consumers Energy has developed a management plan (Consumers Power Company 1994) for these lands according to terms outlined in the Settlement Agreement (Appendix 1). A copy of their plan may be obtained by contacting Consumers Energy, 212 W. Michigan Avenue, Jackson, MI 49201.

Sport Fishing Regulations and Fish Consumption Advisories

Michigan Natural Resources and Environmental Protection Act, 1994, Public Act 451, Part 487, Sport Fishing, gives the State of Michigan the authority to regulate the take of fish, mollusks, amphibians and reptiles. In addition, this part designates "trout" and "warm water" streams (see **Water Quality**). These definitions are used in determining the water quality standards that must be met when NPDES permits are issued. Dissolved oxygen levels >7 mg/l must be maintained in designated trout streams, and dissolved oxygen level >5 mg/l must be maintained in warm water streams. The majority of the Au Sable River watershed consists of designated trout streams (Figure 17). The Michigan Department of Community Health issues fish consumption advisories for Michigan waters. See **Water Quality** for fish consumption advisories in the Au Sable River watershed.

Blue Ribbon Trout Stream Classification

Michigan Department of Natural Resources, Fisheries Division, has established Michigan's Blue Ribbon Trout Stream Program to identify and publicize the state's premiere trout streams and to provide direction for their management, protection, and enhancement. To be designated as a Blue Ribbon Trout Stream, a stream should: be one of Michigan's best trout streams; support excellent stocks of wild, resident trout; be large enough to permit fly casting, but shallow enough to wade; have diverse insect life and good fly hatches; have earned a reputation, at least locally, for providing a quality trout fishing experience; and be clean and clear (MDNR Fisheries Division records). Management of Blue Ribbon streams is directed toward accommodating the needs of all trout anglers: through protection of stocks of wild resident trout; protection and enhancement of trout habitat; and providing adequate public access. The Au Sable River drainage contains 20% (179 mi out of 874 mi total), the most of any watershed in Michigan (Figure 22). These sections all share the above characteristics with the exception of the river below Mio Dam, whose trout fishery is supported by stocking, and the East Branch Big Creek- North which is marginally warm for trout survival.

Navigable Waters

Anonymous (1993) discusses the issues associated with public rights on Michigan waters including navigability. The issues of water law are complex and develop periodically through both legislative and judicial action. A navigable inland stream is 1) any stream declared navigable by the Michigan Supreme Court; 2) any stream included within the list of navigable waters of the United States maintained by the United States Army Engineers for administration of laws enacted by Congress for the protection and preservation of the navigable waters of the United States; 3) any stream which floated logs during the lumbering days, or a stream of sufficient capacity for the floating of logs in the condition which it generally appears by nature; 4) any stream: having an average flow of about 41 cfs; an average width of some 30 feet; an average depth of about 1 foot; capacity for "floatage" during spring seasonal periods; used for fishing by the public for an extended period of time; and stocked with fish by the state; 5) any stream which has been or is susceptible to navigation by boats for purposes of commerce or travel; or 6) all streams meandered by the General Land Office Survey in the mid 1800s (Anonymous 1993).

Navigable waters in Michigan have been divided into two classes, strictly navigable and floatable. The right to public use of navigable waters includes the right of trespass upon the submerged soil but not the adjacent uplands. The public also has the common right of fishing in navigable streams, subject to state regulations.

Federal or state entities have declared the following reaches of the Au Sable River watershed as legally navigable (Anonymous 1993):

1) United States in United States Army Engineering District, Detroit, 1981.
   Au Sable River, Foote Dam 7 miles above mouth.
2) Michigan supreme court
   Au Sable River, Otsego County, downstream from lands owned by Pack Woods & Co., Salling & Hanson, H.W. Sage Co., Wright & Davison in 1888,
   Au Sable River, Iosco County, 30 miles upstream from mouth

Local Government

Local units of government have the authority to impose special ordinances and zoning restrictions that influence use of and conditions in the watershed. County road commissions influence stream sedimentation through installation and maintenance of road-stream crossings. Legal lake levels are set by circuit courts in their respective areas. County drain commissioners, or other designated officials, are responsible for maintaining lake levels, operating lake-level control structures, and maintaining designated drains. No designated drains have been identified in the Au Sable River watershed.

Biological Communities

Original Fish Communities

Documentation of much of the Au Sable River's original fish community is lacking because several major changes to the system occurred as the area was being settled, and major dams were built before much scientific sampling took place within the basin. However, early descriptions of the river and a few records of fishes encountered by early settlers provide some indication of what these communities were like. In addition, alteration of the Au Sable River landscape has been relatively minor in comparison to the extent of change in many other Lower Michigan watersheds, so much can be learned by looking at current conditions. For example, many of the fishes thought to have originally existed in the Au Sable River system currently inhabit the river (Table 16).

In general, the Au Sable River system had exceptionally clear waters and extremely stable flows (Berry 1992). Most of the watershed was forested (see **Soils and Land Use Patterns**). Infiltration of precipitation into the water table was very high (see **Geology and Hydrology**). Riparian areas were completely forested, with the trees providing an important source of woody debris and nutrients to the stream. Retention of woody debris and nutrients in upper reaches of the system was probably high due to the system's hydrologic stability (lack of catastrophic flushing flows) and frequent occurrences of pools associated with logjams and probable beaver activity. Trees lying in the stream, commonly referred to as "sweepers", literally swept and kept items floating downstream. Vincent (1962) used historical accounts to provide the description of the original channel of mainstem below Grayling:

> "In 1874, the bottom of the Au Sable River two miles below Grayling was clean sand and gravel in the center and a strip of dark humus loam along either side (Mather 1874). Banks were lined predominantly by cedar, birch, alder, and willow. Many stumps, fallen trees, leaves, and weeds stabilized the stream banks (Mather 1874; Northrup 1880). Roots and litter from centuries of stream-side vegetation plus the absence of freshets had stabilized the easily erodible sandy stream banks; gradual sorting plus accumulated organic deposits had made a firm, stable stream bottom."

The riparian influence on the stream channel may have lessened further downstream as the river grew too wide to be readily blocked by felled trees. However, large debris jams occurred in the river and seemed to have remained in place for extended periods of time (see **History**).

Upper reaches of the East, South, and North branches of the Au Sable River, the mainstem, and Big Creek-North flowed out of lakes and swamps, and probably had clear, often vegetated, warm waters that cooled further downstream due to groundwater inflows (see **Geology and Hydrology**). Lentic fishes and those typical of small warm water streams were probably common here; species probably included: northern pike, largemouth bass, bluegill, pumpkinseed, rock bass, brown bullhead, yellow bullhead, yellow perch, creek chub, central mudminnow, common shiner, and johnny darter (Richards 1976). The thermally transitional reaches downstream would have had fewer lentic fishes and more cool water, riverine species such as: blacknose dace, longnose dace, mottled sculpin, rainbow darter, hornyhead chub, and northern redbelly dace. Collections made from warm headwater reaches in the 1920s and 1970s typically had 7-12 species of fish (Richards 1976).

High inflows of groundwater in transitional reaches produced cold water conditions downstream. Arctic grayling were very abundant and well documented in these cold water reaches. Historical records showed good fishing for Arctic grayling in the mainstem from less than 5 miles downstream of Grayling to at least 40 miles downstream near Mio, and they may have been abundant even further downstream (Vincent 1962). Miller (1963) cited reports of Arctic grayling being caught in both the North and South branches of the Au Sable River. It is probable that they existed in all moderately sized, cold water reaches of the drainage that now support trout.

Relatively few other fishes may have co-existed with Arctic grayling in cold water reaches of the mainstem, Big Creek-South, and the North, South, and East branches of the Au Sable River. Suckers, a shiner, pike, and whitefish are the only other fishes mentioned by early observers as being associated with Arctic grayling in the Au Sable River (Hallock 1873; Mather 1874; Oatka 1888). Richards (1976) reported that fish species richness in these streams was relatively low in the 1920s and 1972, with typically 7-11 species present at individual sites, and about 30 species among streams. Common resident species in the original fish community probably included: mottled sculpin, slimy sculpin, common shiner, blacknose dace, pearl dace, creek chub, river chub, white sucker, brook stickleback, johnny darter, and round whitefish. These species were found in early collections by Jacob Reighard in 1903, Hubbs in the 1920s, and in later collections by Richards in 1972 (University of Michigan Museum of Zoology records; Richards 1976). Fishes that were difficult to catch, such as lampreys, are probably under-represented in historical collections.

Historic records also documented runs of potamodromous fishes from Lake Huron (and possibly the lower mainstem) into these cold water reaches. McKinley (1933) reported that "Before the river had been harnessed by dams to create power for distant towns, the larger fish had opportunity to ascend the stream. I have seen sturgeon more than 6 feet long and weighing fully a 100 pounds or more in the mainstream near the mouth of the North Branch, at Connor's old bridge. You will see them no more as far up as that. In the spring of the year I have speared many big pickerel [walleye] down in that vicinity in the years of long ago." These fish were apparently moving upstream from the lower mainstem or Lake Huron for spawning. Early settlers, Nick Shellenbarger and Will Stephan used to spear "[Arctic] grayling, suckers, and pilot fish [round whitefish]" in the mainstem, starting at the mouth of the South Branch and heading upstream for 10 miles (Miller 1963).

Runs of steelhead (migratory rainbow trout) from Lake Huron were also documented in the upper Au Sable River. Westerman (1961) mentioned that all trout streams on Lake Huron south to the Rifle River witnessed runs of rainbow trout. The Michigan Department of Conservation (1966) stated that "large runs of steelhead from Lake Huron were common in the Grayling area of the Au Sable". Stoll (1951) reported that "14 pound rainbows were splashing in the pools and the heads and tails of riffles from Grayling to the Huron coast".

Aside from records of lake sturgeon (see **History**), we found no historical records describing the pre-settlement fish fauna of the Au Sable River below Mio. However, we can use historical descriptions of the river at that time and our knowledge of the present condition of the lower mainstem to make projections of what it might have been like. McKinley (1933) stated, "The river is not navigable save only for a short distance at its mouth, for it is turbulent and swift at many points, the natural current being about 3 miles per hour and in places it increases to 6 and 7 miles per hour. It has many deep holes, followed by shallow water, which ripples in the sunlight over pebbly and sandy bottoms". From Mio down to Foote Dam, the Au Sable River was a large, highly groundwater-fed river that descended rapidly. Eighty-five percent of the flow at Mio was attributed to groundwater under normal conditions (Coopes et al. 1974). Substrates were relatively coarse along much of its length, and very coarse (cobble, boulder) in high-gradient areas. Being highly fed by groundwater, summer conditions were characterized by high current velocities, and cold-cool temperatures that fluctuated somewhat on a daily basis. Sand and gravel substrates, and somewhat lower velocities, would have been more prevalent in the downstream-most reaches of lower river (roughly below Foote Dam) which had a lower gradient and flowed over lacustrine sands and gravels (Farrand and Bell 1982). This stretch would have included substantial populations of large-bodied fishes such as: Arctic grayling (especially in upstream reaches), round whitefish, walleye, lake sturgeon, smallmouth bass, greater redhorse, silver redhorse, golden redhorse, northern hog sucker, white sucker, northern pike (especially at the river mouth), and possibly burbot. Smaller fishes would have included: logperch, blackside darter, rainbow darter, johnny darter, river darter, channel darter, blacknose dace, longnose dace, common shiner, bluntnose minnow, creek chub, blackchin shiner, stonecat, river chub, mottled sculpin, and brook stickleback. In addition, Lake Huron fishes probably migrated to rapids in this reach for spawning. The original potamodromous fauna probably included lake whitefish, round whitefish, lake herring, longnose sucker, white sucker, lake sturgeon, lake trout, and walleye. Other species, such as yellow perch and northern pike would have migrated upstream to spawn in backwater habitats. Reports of historic fisheries for "whitefish, lake trout, herring, yellow pickerel [walleye], and perch" in Lake Huron near the river by Thornton (1987) suggest that migrating fish may have been targeted. Seasonal camps by Native Americans along the lower mainstem also targeted potamodromous fishes (see **History**). Fish species richness in the lower mainstem was seasonably variable, probably ranging from about 25-40 species.

Modifying Factors

European settlers altered the Au Sable River system and its fish fauna in a variety of ways. Human activities influenced the landscape, channel characteristics, hydrology, water quality, and fish communities of the river. Though the Au Sable River has healed somewhat from effects of these activities, humans left some indelible marks on the system. We will briefly highlight some of the more significant activities and their effects.

Arctic grayling stocks were heavily exploited almost as soon as settlers discovered them. Their uniqueness attracted anglers throughout North America and Europe. Arctic grayling were easy to catch and were harvested and sold in great quantities. Catches as high as 5,000 Arctic grayling from a 5 mile section of the North Branch Au Sable River were reported by anglers, fishing commercially with hook and line (Norris 1878). Analysis of historic records by Vincent (1962) suggested that over-fishing was the main cause for the decline of Arctic grayling in the Au Sable River. These records suggested that population declines began shortly after the arrival of the railroad line in Grayling, and that populations were reduced before peak lumbering and the introduction of brook trout to the mainstem (Vincent 1962). By the mid-1880s Arctic grayling had disappeared from parts of the mainstem, prompting public demands for brook trout stocking (Westerman 1961; Vincent 1962).

Introduced species arrived early in the Au Sable River and continue to play major roles in its present fish community. The first recorded stockings of brook trout (1885) and rainbow trout (1876) in Michigan were in the Au Sable River (Westerman 1961). Once established these species (competitors with Arctic grayling) probably ensured that Arctic grayling would never return to the Au Sable River (Vincent 1962). The mainstem was stocked with brown trout in 1891, and in 1892, the South Branch Au Sable River and the East and West branches of Big Creek-South were stocked with brown trout (Westerman 1961). These species, via natural reproduction or stocking, provide the Au Sable River's current salmonid fishery and have been stocked in many lakes in the watershed. Naturalized salmonids provide a valuable sport fishery below Foote Dam. Warm and cool-water species have been stocked into lakes and impoundments throughout the system (Table 17).

Logging affected the river in a variety of ways. Clearing of forests dramatically reduced the amount of precipitation lost to evapotranspiration and probably increased the river's discharge to abnormally high levels. Initial logging focused on areas adjacent to watercourses that could be used for transporting logs. Riparian forests and accumulations of instream woody debris, which had been developing over centuries, were cleared to make it easier to float logs downstream. Skidding and rolling of logs into rivers tore up stream banks, adding much sediment to the stream. Many raw banks still visible today, such as those along the lower mainstem, have yet to re-vegetate. Soil erosion from denuded uplands increased, making the river's formerly clear water "muddy" and "dirty" (Miller 1963).

Temporary dams were created for storing spring runoff and to aid in floating logs downstream. Dams would suddenly be opened to provide a flushing surge of water for carrying logs downstream (Vincent 1962). The churning mass of logs, riding on flood flows, scoured the bed and banks of the river, especially in shallow areas or in stream meanders. These unusual flow levels and debris loads tended to widen the channel. These effects seem especially pronounced in the North Branch Au Sable River (see **Channel Morphology**). The once stable stream bed, now carried a heavy load of sand that filled in holes and smothered coarser substrates. Turbidity increased as logs collided with each other and with the stream's bed and banks (Miller 1963). Logging dams fragmented the stream and created extensive areas of slack water. For example, dams impounded the North Branch for 30 miles (Vincent 1962). Dams and the loss of riparian forests elevated temperatures to levels that may have been unsuitable for coldwater fishes. For example, Quid (1877) found no Arctic grayling in the North Branch Au Sable River until below Dam 4, the farthest downstream logging dam. Sites surveyed by Hubbs in the 1920s contained fewer coldwater fishes than when they were resurveyed by Richards in 1972, possibly indicating a change in the thermal characteristics of the river with the removal of old logging dams and recovery of riparian areas (Richards 1976).

Reports suggested that lumbering activities also hurt the fishery in Lake Huron around the mouth of the Au Sable River. MacDonald (1942) stated that the fishery during the lumbering period was “negligible”. According to fishermen, waste materials from sawmills entered the river, eventually reaching Lake Huron (MacDonald 1942). Conflicts arose between lumbermen and fishermen over the issue as early as 1866 (Thornton 1987), but use of the river for lumbering waste disposal continued. Fishing improved when use of the river for waste disposal from logging finally stopped (MacDonald 1942).

Fishes require distinct spawning, growth, and refuge habitats in their life cycle (Schlosser 1991). Equally important, fishes must be able to freely migrate between these habitats (Figure 16). If any one habitat is lacking or if the ability to migrate from one to another is restricted, the population can become restricted or locally extinct. Migrations allow fish populations to fully use the best available feeding, growth, and refuge habitats within the aquatic system, and thus realize the potential of the river system. Migration corridors also provide a means for populations to recolonize disturbed areas. Dams in the Au Sable River system prevent the river from realizing it’s potential to support thriving fish populations.

Hydropower development on the mainstem caused dramatic and long lasting changes in the river, and has been discussed in detail (see **Dams and Barriers**). Six major hydropower dams on the lower mainstem fragment the river system, blocking fish migrations and restricting fish populations to limited areas of the river. Potomadromous runs of fishes into the Au Sable River above the dams began declining as early as 1911 with the construction of Cooke Dam. Dams reduced fish reproductive success and later population levels by preventing access to spawning habitats. High-gradient, cold-cool water reaches, valuable as spawning areas for many Great Lakes fishes, became warm water impoundments with limited fishery potential. Dams warmed temperatures in downstream reaches to levels less desirable for coldwater fishes and prevented natural downstream transport of sediment and woody debris. Peaking operations at hydropower dams produced dramatic daily flow fluctuations and caused excessive erosion below some dams. Several problems with peaking operations have been resolved in the Settlement Agreement recently reached between Consumers Energy and various state and federal agencies (see Appendix 1).

Many low-head dams and lake-level control structures exist throughout the drainage (see **Dams and Barriers**). They fragment the system, block upstream migrations of fish, and alter stream temperatures. The dams affect downstream reaches to varying degrees, depending on how water levels are manipulated. Lake-level control structures often alter the hydrologic stability of the streams. Maintenance of constant water levels in lakes and ponds eliminates natural water level fluctuations that are important for wetlands. Constant lake levels encourage development and encroachment on shorelines, further exacerbating losses of wetlands. Maintaining constant lake levels disrupts the outlet stream’s natural flow regime, and may result in downstream drought or flood conditions detrimental to aquatic organisms (Nuhfer et al. 1994).

Urban development, though limited within the watershed, has led to some point and nonpoint source pollution problems (see **Water Quality**). Wastewater treatment plant effluents enriched portions of the South Branch Au Sable River below Roscommon and the mainstem below Grayling. These problems were addressed in the 1970s shortly after passage of the Federal Clean Water Act. In headwater areas, many homes along the river use well water (groundwater) and then discharge it back to the watershed as surface water or sub-surface water. During summer, this water returns to the system warmer. It was estimated that water withdrawal in the catchment of the Au Sable River at Mio increased by 29% between 1960 and 1970 (Coopes et al. 1974). This may become an even greater problem due to increasing residential development within the watershed (see **Soils and Land Use**).

Current Fish Communities

Comprehensive surveys conducted by Dr. Carl L. Hubbs in the 1920s, J. Scott Richards in 1972, Consumers Power Company in 1991 and various MDNR, Fisheries Division surveys, show 94 species of fishes as now or recently in the Au Sable River drainage. Of these, 77 are native and now exist within the drainage, 1 (Arctic grayling) is native but extirpated, 2 are native but their current status is unknown, 9 were intentionally introduced (8 now exist and the current status of one is unknown), and 5 colonized the drainage via canals or dispersal from previous introductions and now exist (Table 16). Three native fishes within the drainage are now listed by the state of Michigan as being endangered, threatened, or of special concern- lake sturgeon, river darter, and channel darter (MDNR, Wildlife Division, Natural Features Inventory). Distribution maps for each species are in Appendix 3.

There has been no comprehensive survey of fishes in the drainage since Richards sampled it in 1972. He sampled sites previously surveyed by Hubbs in the 1920s, using the same methods as Hubbs. His findings, reported in Coopes et al. (1974) and Richards (1976), describe fish community changes in the Au Sable River and provide the basis for much of our discussion of current fish communities in the major river mainstem valley segments. We will present his summary data on stream conditions, species diversity, and most common species. We identified most common species as those occurring at more than 33% of the sites in a given habitat type (Richards 1976). He grouped sites into four habitat types based upon their discharge and normal maximum temperatures. The groups were warm headwaters (<100 cfs and >70^{o}F), cold water, moderate flow (<300 cfs and <70^{o}F), large river (>300 cfs), and below impoundments. Actual data for fish collections at each site are presented in Coopes et al. (1974).

The mainstem, East Branch, North Branch, and South Branch Au Sable rivers, Big Creek-North, and Big Creek-South drain lakes and wetlands in their upper reaches, and are predominantly warm- to cool-water streams, too warm or marginally warm for trout (Figure 8). Of these streams, Richards sampled 5 stations on the East Branch, North Branch, and South Branch Au Sable River in 1972. Fish species richness at these sites ranged from 7-12 species with an average of about 9 species per site. Most common species included: mottled sculpin, central mudminnow, northern pike, hornyhead chub, common shiner, bluntnose minnow, blacknose dace, creek chub, white sucker, rock bass, bluegill, largemouth bass, johnny darter, yellow perch, and blackside darter (Richards 1976). Fish collections from 1972 were fairly similar to those from the 1920s, suggesting that no major changes had occurred over the 50 years. Richards thought that declines in the frequency of occurrence of river chub and brook trout (from 60% and 40% of sites to zero) may have been related to changes in water quality or competition from other species. A 1992 MDNR, SWQD survey of the South Branch Au Sable River at Steckert's Bridge (in a reach where the river changes from warm to cold) reported 8 species of fish and characterized the fish community as "good" (Morse 1994). It included many of the above species, plus brown trout, a competitor of brook trout and a salmonid generally more tolerant of warmer water. Similar surveys in transitional reaches of the mainstem at Pollacks Bridge (5 mi upstream of Grayling) and Penrods Canoe Livery (in Grayling) contained both warm- and cool-water fishes (Morse 1994). The upstream site contained 12 species, with northern brook lamprey, brook trout, creek chub, blacknose dace, mottled sculpin, white sucker, and johnny darter being most abundant. The warming influence of the Grayling dam on water temperatures was evident at the downstream site which had more species (17), more brown trout, fewer brook trout, and several lentic fishes including rock bass, bluegill, pumpkinseed, smallmouth bass, and yellow perch. The fish community at both sites was rated as "good".

The mainstem, East Branch, North Branch, and South Branch Au Sable rivers, Big Creek-North, and Big Creek-South accrue groundwater in their downstream reaches, becoming cold water streams (Figure 8). The 19 cold water, moderate flow stations sampled by Richards (1976) included the lower reaches of all these tributaries and the mainstem down to the mouth of the South Branch Au Sable River. Fish species richness at these sites was lower than at warmer upstream reaches (which would be expected given the cooler temperatures), typically ranging between 7-9 species (Richards 1976). In 1972, the most common fishes in these reaches included: brook trout, brown trout, mottled sculpin, slimy sculpin, common shiner, blacknose dace, creek chub, white sucker, and johnny darter. Increased brown trout, slimy sculpin, and round whitefish (all coldwater species) suggested that these reaches had gotten colder between the 1920s and 1972. Decreased temperatures may have resulted from removal of old logging dams or increased shading due to forest regrowth (Richards 1976). Less frequent presence of blacknose shiners, common shiners, pearl dace, and river chubs in the 1972 collections might also reflect decreased temperatures, or an increase in sand and silt in these reaches since the 1920s. Comprehensive surveys would aid in describing how these reaches have changed since 1972.

Self-sustaining populations of brook trout and brown trout have existed in upper mainstem, North Branch, and South Branch Au Sable rivers since these waters were stocked in the late 1800s. Population estimates of brown and brook trout in several reaches of these waters have been made by the MDNR, Fisheries Division nearly every year since 1957 (Figures 23 and 24). These data demonstrate the variability of trout populations over time, with variations being attributable to many possible causes including habitat and water quality changes, hydrologic and climatic changes, and changes in angling pressure, regulations, and methods. Explanation of these trends has been complicated by simultaneous changes in several factors, and a lack of past data for testing the influence of suspected causes. However, analyses of these data have contributed greatly to our knowledge of trout biology and population ecology, and provided much of the scientific basis for trout research and management in Michigan and the United States (Table 18).

Richards (1976) grouped downstream collection sites into “large river” and “below impoundment” habitat categories. We will briefly discuss changes that occurred among these habitats between the 1920s and 1972 before continuing our description of their present fish communities. The “large river” habitat category included 6 stations on the mainstem between the mouth of the South Branch Au Sable River and Lake Huron. Richard (1976) noted substantial species shifts in this habitat type. Declines of rainbow trout and slimy sculpin, both coldwater species, and of river chub and longnose dace, fishes intolerant of the silt and turbidity, suggested a change in water quality. Greatest species shifts were observed among the 4 “below impoundment” stations on the mainstem from Mio downstream. Longnose dace, blackchin shiner, river chub, rosyface shiner, and redfin shiner, fishes intolerant of silty and turbid conditions (Trautman 1981), were absent from the 1972 collections. The mimic shiner, a species relatively tolerant of silt and turbidity, was absent from these four stations in the 1920s but abundant at all of them in 1972. Richards (1976) attributed the general decline in fish populations here to hydroelectric peaking operations and the influence of these aging impoundments on downstream water quality.

From Wakeley Bridge to the upper end of Mio Pond, the river grows considerably in size as it receives waters from the North Branch and South Branch Au Sable rivers, and Big Creek-South. Though summer stream temperatures in rivers typically warm downstream, temperatures decline along this river mainstem valley segment due to groundwater accrual from adjacent ice contact deposits and tributaries draining them (Farrand and Bell 1982). Lowest stream temperatures were at the downstream end of this segment at Parmalee Bridge, just above Mio Pond (Coopes et al. 1974). Three collections were made in this mainstem valley segment in 1972 (Coopes et al. 1974). The number of fish species per site ranged from 7-14, and averaged 11. Most commonly collected fishes were brook trout, brown trout, mottled sculpin, slimy sculpin, common shiner, blacknose dace, creek chub, and white sucker. Sampling by SWQD in 1992 at Parmalee Bridge (Morse 1994), revealed a “good” fish community having 14 species, the most common ones being brook trout, creek chub, blacknose dace, longnose dace, mottled sculpin, white sucker, and rainbow darter. More thorough, multiple pass electrofishing surveys of the mainstem at Parmalee Bridge in 1990 (Lawler, Matusky, and Skelly Engineers 1991a) revealed a more species-rich community of 22 species (Table 19). Coldwater fishes composed 58% of the catch by number but 49% of the catch by weight, and coolwater fishes made up 29% of the numerical catch and 50% of the catch by weight. Unidentified whitefish (probably round whitefish), brown trout, white sucker, and blacknose dace were the most abundant species, comprising 87% of the catch weight. The Au Sable River's round whitefish population is the only known riverine population of the species in Michigan's Lower Peninsula, and is likely a remnant isolated by dams from the Lake Huron population.

Shortly below Parmalee Bridge, the River enters Mio Pond. Here the Au Sable River warms considerably, and the fish communities of the pond and below the dam reflect this. Catch composition in surveys of Mio Pond done by USFS and MDNR, Fisheries Division in 1996 show low numbers of coldwater species (brown trout and round whitefish), increased abundance of coolwater species (especially white sucker, northern pike, and walleye), and low numbers of many warmwater fishes, except for bowfin which were abundant (Table 20). Comparison of riverine fish community samples taken above and below Mio Pond also shows this warming effect. Coldwater species make up much less of the catch (composition by weight drops from 49% to 1%), and coolwater species become considerably more abundant, as their weight in the catch increased from 50% to 98% (Table 19). Similarly, numerical abundance of coldwater fishes decreases and that of warmwater species increases. Declines in brown trout and round whitefish and increases in greater redhorse, northern hogsucker, and white sucker are especially notable. Round whitefish did not appear at any of the 1990 Au Sable River survey sites below Mio Dam (Table 19). Warmer conditions below Mio Dam are also indicated by initial appearances of several warm- and cool-water fishes, such as walleye, greater redhorse, logperch, smallmouth bass, stonecat, and largemouth bass.

From below Mio Dam to Alcona Pond, the Au Sable River accrues considerable groundwater (see **Geology and Hydrology**). The river cools and the fish community reflects this. Catches by weight of coolwater fishes declined considerably from an average of 108 lbs/pass below Mio Dam to 12 lbs/pass above Alcona Pond, and coldwater fishes made up slightly greater portion of the catch by weight (Table 19). On a percentage basis, numerical abundance of coldwater fishes increased, and that of cool- and warm-water species declined. Still, warm summer temperatures may be limiting natural reproduction of salmonids in this reach. Brown and rainbow trout populations here are largely sustained by stocking because natural reproduction is negligible.

In Alcona Pond, the Au Sable River slows down again, warms, and becomes more thermally stable. Species typical of low velocity, cool environments are most common here. Most common fishes in decreasing order of abundance by weight were: white sucker, bowfin, smallmouth bass, rock bass, brown bullhead, northern pike, and walleye (Table 20). Downstream of Alcona Pond, the Au Sable River flows freely for about 11 miles before being impounded by Loud Dam. Declining stream temperatures testify to the river's continued accrual of groundwater along this reach, but temperatures apparently do not recover enough to support large numbers of coldwater fishes. Though some coldwater species, such as brown trout and longnose dace occur, coolwater species seem best adapted to its present thermal regime. Coolwater fishes composed 96% by weight of the catch in the river upstream of Loud Pond (Table 19). Greater redhorse, northern hogsucker, and white sucker represented most of the biomass, with walleye, river chub, and logperch being of lesser importance.

From Loud Pond to Foote Pond, the Au Sable River flows through a series of four back-to-back impoundments. Riverine connections to Loud Pond are apparent in the fish survey data, as there are abundant populations of golden redhorse, greater redhorse, and white sucker (Table 20). Bowfin were very abundant in Loud Pond, comprising nearly a quarter of the catch by weight, as were brown bullhead, yellow bullhead, rock bass, and pumpkinseed. Abundance of suckers and redhorse decline progressively downstream through the ponds, as distance from upstream riverine habitat increases. Downstream increases in the catch of bass and sunfishes also testify to the change from a cool, riverine environment to one characterized as warmer and more lentic (Table 20).

A variety of potamodromous species now use the river below Foote Dam. Great Lakes fishes found in this portion of the river include: rainbow trout (steelhead), chinook salmon, coho salmon, lake sturgeon, white sucker, channel catfish, white bass, alewife, walleye, yellow perch, freshwater drum, smelt, white sucker, longnose sucker, emerald shiner, gizzard shad, spotfin shiner, and brown trout. The influence of a Great Lakes connection on fish species richness and standing crops is evident when surveys of this reach are compared to sites above Foote Dam (Table 19). Species richness is highest in this reach (28 species). The total weight of fish caught per pass is nearly 4 times that of the three upstream riverine sample sites (Table 19).

The Pine River enters the mainstem along this most downstream reach, and is the only tributary to the Au Sable River that is accessible by Great Lakes fishes. The Pine River is the product of the confluence of many small, cool streams that drain lacustrine sands and gravels. Typical fishes of these streams include: brook trout, brown trout, rainbow trout (usually steelhead), creek chub, hornyhead chub, blacknose dace, mottled sculpin, mudminnow, brook stickleback, white sucker, johnny darter, rainbow darter, and sea lamprey ammocoetes. The presence of small rainbow trout and sea lamprey ammocoetes indicates that the lake-level control structure at Van Etten Lake allows for seasonal upstream passage of some potamodromous species. Fishes generally move through the structure when the lake is being lowered to and maintained at its winter level.

Threatened and Endangered Fishes

Three state threatened or endangered fishes occur or occurred in the Au Sable River (lake sturgeon, channel darter, and river darter). All are associated with reaches of the river that have cool summer temperatures, and are large-sized and free-flowing. This habitat is almost entirely impounded by the four lowermost dams on the Au Sable River. Remnant populations of these species are now restricted to the few patches of riverine habitat that still exist. Rehabilitation of the free-flowing nature of these reaches through dam removal is the key to improving the status of all of these populations.

The state threatened lake sturgeon lives in large rivers and lakes, making upstream migrations to spawn over coarse substrates (large gravels to boulders) in riffles and rapids (Trautman 1981; Becker 1983; Balon 1975). Lake sturgeon formerly migrated up the mainstem at least 117 miles to the mouth of the North Branch Au Sable River (McKinley 1933; Goodyear et al. 1982), and was reported as “abundant” in the Au Sable River (Donaldson 1983). Spawning runs of lake sturgeon from Lake Huron to the rapids of the Au Sable River were eliminated by dam construction. Unconfirmed sitings indicate that a few individual sturgeon may have been upstream of the dams as late as the 1940s (N. Thornton, local historian, personal communication). Lake sturgeon now use the river reach below Foote Dam that is connected to Lake Huron, and have been observed attempting to spawn just below the dam (Goodyear et al. 1982; S. Sendek, personal observation).

The Au Sable River contains possibly the only inland population of the state-threatened channel darter in Michigan. Schultz’s (1986) collections from sites where channel darters historically lived revealed the species presence only in the Au Sable River drainage. Trautman (1981) noted that the species occurs in lakes and large rivers over clean sand and gravel bottoms. It spawns in and prefers areas of small gravel near, but protected from, moderate to swift current (Schultz 1986). The channel darter was collected in 1986 from the mainstem below Five Channels and Foote dams, the Pine River at both Kings Corner and Mikado roads, and Van Etten Creek along Barlow Road (Schultz 1986). In

Michigan, it also occurs in Lake St. Clair and the St. Clair River. Because of the species' rarity, Latta (1998) proposed that its status be changed from threatened to endangered.

The state-endangered, river darter inhabits large rivers and lakes in association with gravel substrates (Trautman 1981; Schultz 1986). Hubbs collected a river darter below Foote Dam in 1925 (L. Scrimger, MDNR Wildlife Division Natural Features Inventory, unpublished data). Schultz's (1986) survey of the mainstem below Foote Dam failed to capture this species, but sampling efficiency was reduced by high flow conditions. The only recent collections of river darter were from Lake St. Clair (W. Latta, Institute for Fisheries Research, Ann Arbor, personal communication).

Aquatic Invertebrates

The invertebrate community of a site can provide a more direct indication of habitat problems because of its immobility relative to fish or other large aquatic organisms. The composition of the invertebrate community can help pinpoint specific problems because individual species vary in their tolerances to stream temperature, nutrient, substrate, and current velocity conditions. For example, studies of the invertebrate communities in the mainstem near Grayling and the South Branch Au Sable River near Roscommon documented the effects of wastewater treatment plant effluents on the river, and changes resulting from improvements in sewage treatment (Michigan Department of Conservation 1966; Coopes et al. 1974).

Quigley (in Coopes et al. 1974) did the only comprehensive sampling of aquatic invertebrates in the Au Sable River. In the summer of 1972, he sampled 33 sites on the mainstem and its major tributaries. He looked at species diversity patterns and community composition by grouping invertebrates based upon their tolerance to environmental conditions (Coopes et al. 1974). Tolerant organisms could withstand (and often flourished under) a variety of adverse conditions; facultative organisms could tolerate a wide range of conditions and often responded positively to organic enrichment; intolerant organisms could tolerate only a narrow range of conditions and were rarely found in low-quality waters. As species diversity increased, the percentage of intolerant organisms increased and that of facultative insects decreased.

Data from Coopes et al. (1974) provide a picture of the Au Sable River insect community in 1972. Surveys by MDNR, SWQD in the 1990s help in describing the current status of some reaches. In the upper mainstem (including Bradford Creek) down to Grayling species diversity was high, but declining in a downstream direction, with intolerant insects comprising a third of the community (Coopes et al. 1974). Insect species diversity increased noticeably below Grayling, and remained high downstream to Mio Pond. In this reach, 43% of the insects in the samples were classified as intolerant. In 1992, the invertebrate communities at the site upstream of Grayling (Pollacks Bridge) and two downstream sites (Penrod's Canoe Livery and Parmalee Bridge) were all characterized as "good (slightly impaired)" (Morse 1994).

The Grayling to Mio reach of the mainstem is especially noted for the diversity and number of its fly hatches, which provide constant trout feeding throughout the year. Some of the most notable hatches include: Michigan caddis fly (*Hexagenia limbata*), brown drake (*Ephemera simulans*), Hendrickson (*Ephemerella rotunda*), white fly (*Ephron album*), sulphur (*Ephemerella dorothea*), blue-winged olive (*Baetis vagans*), little black caddis (*Chimarra aterrima*), and trico (*Tricorythodes stygiatus*).

Samples from the East, North, and South branches of the Au Sable River and Big Creek-South all showed relatively high diversity, with the percentage of intolerant insects generally increasing downstream (reflecting groundwater accrual). However, point-source influences (e.g. Roscommon wastewater treatment plant on the South Branch Au Sable River and the Grayling Fish Hatchery on the East Branch Au Sable River) and different substrates at sampling sites seemed to interrupt downstream trends in species diversity and percent intolerant insects (Coopes et al. 1974).

In 1972, insect species diversity in the lower mainstem was lowest at five sites located below impoundments (Coopes et al. 1974). Quigley also noted that the percentages of intolerant insects in samples below Mio, Alcona, and Foote Ponds were unusually low, but seemed normal below Five Channels Dam (Coopes et al. 1974).

Recent surveys indicate continued adverse effects of impoundments on the lower Au Sable River's invertebrate fauna. Samples of invertebrates from riverine reaches above and below Mio, Alcona, and Loud ponds show dramatic declines in numbers of species collected below the dams (Figure 25). The numbers of species collected from sites immediately downstream of Mio, Alcona, and Loud ponds were 88%, 81%, and 94% less than those from sites just upstream of the ponds. Comparisons of densities of organisms on cobble and boulder substrates in riverine reaches above and below the impoundments showed upstream sites having 1.7-19.2 times more organisms per unit area (Figure 26). Numbers of mayfly, stonefly, and caddisfly species, taxa generally considered intolerant of adverse conditions (Coopes et al. 1974), were also much higher above the impoundments than below them (Figure 27). Low numbers of taxa and densities of organisms downstream of Five Channels, Cooke, and Foote dams suggest that they may also be affecting the benthic community. Detailed analyses of these data may suggest specific mechanisms by which these impoundments degrade the benthic community. Surveys below impoundments are needed to evaluate the benthic community's present status, especially since run-of-river flows have been initiated.

In addition to a lack of current data on benthic insects in the Au Sable River, no information was available on distributions of mussels or other benthic invertebrates within the drainage. A complete inventory of the river's benthic invertebrate community (including mussels) is needed.

Amphibians and Reptiles

Ten species of frogs and toads and seven species of salamanders use aquatic habitats within the Au Sable River watershed (Table 21). None are listed as endangered, threatened, or of special concern by the Michigan Natural Features Inventory. A complete inventory of amphibians and reptiles within the Au Sable River watershed is needed.

Eleven species of snakes and one lizard, the five-lined skink, are found within the Au Sable River watershed (Table 21). The Massasauga rattlesnake, which typically resides in marshy areas, is listed as "Special Concern." Six species of turtles (Table 21) have been recorded in the watershed. Two, the wood turtle and the Blanding's turtle, were listed as being of "Special Concern" by the Michigan Natural Features Inventory. Primary threats to these two species include being killed on roads, alteration or loss of wetland habitats, nest predation, and collection for use as pets (Harding and Holman 1992).

Birds

The river, lakes, and wetlands of Au Sable River watershed provide habitat for a variety of game and non-game birds (Table 22). Several species of ducks, geese, and mergansers nest and forage along the river, and woodcock, grouse, and turkeys forage and travel within its riparian corridor. The state-threatened, common loon breeds on tranquil lakes within the watershed, and trumpeter swans were reintroduced in 1993. Stream edge habitats are used by several species of shorebirds and wading birds, such as great blue herons. Several species of fairly rare raptors also occur. Active territories of at least 20 bald eagle pairs and 3 osprey pairs are located along lakes, rivers, and wetlands within the watershed (J. Weinrich, MDNR, Wildlife Division, personal communication). The bald eagle is a state-and federally threatened species and the osprey is a state-threatened species. The state-threatened, red-shouldered hawk also is present within the watershed. It prefers to nest in mature floodplain forests and forages on frogs, snakes, crayfish, and young waterbirds (Brewer et al. 1991). Maintaining stands of old growth trees is important for these species and other birds such as the northern goshawk (a species of special concern) and pileated woodpecker.

Fire-maintained prairies and jack pine barrens on outwash plains in the Au Sable River drainage are important to several species of birds. These areas compose most of the nesting habitat of the state and federally endangered, Kirtland's warbler. In 1993, over 99 percent of the 485 singing male Kirtland's warblers in the world nested here (J. Weinrich, MDNR, Wildlife Division, personal communication). The state-threatened prairie warbler also uses these areas for breeding (Brewer et al. 1991). Less renowned, uncommon birds also associated with different seral stages of jack pine barren and prairie communities in the watershed include upland sandpiper, black-backed woodpecker, Brewer's blackbird, and spruce grouse.

Mammals

Extensively forested wetland, riparian, and upland areas of the Au Sable River watershed serve many mammalian species in a variety of ways (Table 23). For example, wetlands adjacent to streams provide critical yarding areas for white-tailed deer and a refuge from disturbance for many species. The stream and its riparian corridor provide food, cover, and travel routes for game species including: black bear, bobcat, river otter, muskrat, mink, raccoon, and a variety of non-game species. Consequently, the watershed is a major producer of game mammals such as white-tailed deer, black bear, gray squirrel, fox squirrel, cottontail rabbit, snowshoe hare, and bobcat. Large populations of fur-bearing mammals such as coyote, red fox, gray fox, beaver, river otter, raccoon, muskrat, mink, striped skunk, opossum, and badger also occur. Elk from the prospering herd in the Gaylord-Atlanta area occasionally stray southward into the watershed. The reintroduced, and state-threatened, American (pine) marten lives in at least 5 of 8 counties in the watershed (Table 24). This species and the woodland vole, a resident in the watershed and species of special concern, thrive in tracts of mature forest and are vulnerable to logging activities (Kurta 1995).

Other Natural Features of Concern

Ten invertebrate and 17 plant species in the watershed are classified as endangered, threatened, or of special concern (Table 24). Nine of the 10 listed invertebrates are terrestrial locusts, butterflies, and moths. The tenth listed invertebrate, the spike-lipped crater, is a snail that lives in cedar swamps and small lakes along drainages in areas of irregular topography and transitions between northern hardwood and coniferous forests (Y. Lee, Michigan Natural Features Inventory, personal communication). These habitats often exist where groundwater emerges from springs and represent the headwaters of cold water streams.

The geologic and disturbance history of the Au Sable River landscape produced conditions for several distinct plant communities, some of which contain relatively rare species (Table 24). Many listed plants can be roughly grouped by the habitats where they were most often found. Four species: prairie agoseris, rough fescue, Hill's thistle, and Allegheny plum are associated with dry sand prairie and pine barren habitats. Ram's head lady-slipper and calypso orchids are often in cedar swamps and calcareous wetlands, while fleshy stitchwort and James' monkey-flower are associated with groundwater springs. Showy coneflower and Pitcher's thistle occur in inter-dunal wetlands along the Lake Huron shoreline. Two species are often in predominantly old growth forests: whorled pogonia in mature stands of northern hardwoods, and false violet in wet, hummocky white pine forests.

Protection of several key habitats will serve to benefit many of the rare species discussed above. Protection of coniferous forests in headwater wetlands has the potential to benefit rare plant and invertebrate species, in addition to maintaining the quality of downstream cold water stream communities. Maintaining mature or old growth forests, especially those in wetlands and riparian areas (but also in some upland areas), can benefit many species including a variety of rare birds, reptiles, mammals, and plants. Protection of forests along riparian corridors can also: help maintain high water quality; provide migration corridors that connect isolated animal populations; and benefit aquatic and riparian organisms by providing a ready source of woody debris to streams. Protection of inter-dunal wetlands along the Great Lakes will help sustain populations of several rare species. Populations of several rare birds and plants will be bolstered through protection of fire-maintained, open prairie and savannah habitats occurring in coarse-textured, outwash plains. In fact, the Michigan Natural Features Inventory identified the prairie and savannah habitats of the Grayling Outwash Plain as the most threatened landscape in northern Michigan for three main reasons: it is critical for Kirtland's warbler, secretive locust, and Hill's thistle; it provides critical jack pine barren and dry prairie ecosystem habitats; and it is important for several birds whose populations are declining (D. Pearsall, MDNR Wildlife Division- Michigan Natural Features Inventory, personal communication).

Pest Species

Pest species are those which have been introduced, either accidentally or intentionally, and pose a significant threat to native species or their habitats. Pest species often do not pose any threat unless present in high densities.

Several aquatic pest species are found in the Au Sable River system. Sea lamprey are restricted to the mainstem below Foote Dam, which bars upstream movement, and the Pine River. Chemical treatments to kill larval sea lamprey are conducted every three to five years (D. Lavis, United States Fish and Wildlife Service, personal communication).

Whirling disease (*Myxobolus cerebralis)* spores were detected in brook trout and brown trout in the North Branch Au Sable River in 1995 and the mainstem several miles downstream of the North Branch Au Sable River (at Parmalee Bridge) in 1996 (MDNR Fisheries Division, unpublished data). Whirling disease spores may also have been transported in the river downstream of infected sites, because the spores remain viable for 25+ years (J. Hnath, MDNR, Fisheries Division, personal communication). Whirling disease is thought to have entered the river through illegal, private stockings of infected trout. Whirling disease can be lethal to juvenile trout when densities of spores, *Tubifex tubifex* (a worm that is the parasite's intermediate host), and fish are sufficiently high. Rainbow trout are most susceptible to the disease, followed by brook trout, then brown trout. To date whirling disease spores have not been detected in the mainstem upstream of the North Branch Au Sable River or in the East and South branches of the Au Sable River. There is a need to minimize further introductions of whirling disease and other pathogens to the Au Sable River, by requiring that stocked fish be certified disease-free.

Ponds and lakes provide a foothold for several other aquatic invaders. Zebra mussels were identified in Foote Pond in 1994 and Cooke Pond in 1998 by Consumers Power Company personnel, and have also been identified in Lake St. Helen (Anonymous 1995). Downstream drift of larval zebra mussels (veligers) from Lake St. Helen may result in populations becoming established in the South Branch Au Sable River and downstream reaches of the mainstem. Higher zebra mussel abundance may be expected in the more suitable, lentic habitats of impoundments on the lower mainstem. Common carp are in lakes and impoundments throughout the system. Rusty crayfish, a southern species, were probably introduced into the watershed by anglers who used them for bait. They often exclude native crayfish through competition, being most common in cool-warm riverine and lentic habitats. They were the dominant crayfish in the mainstem above Grayling in 1996 (A. Nuhfer, MDNR Fisheries Division, unpublished data), and were the only species collected in riverine and lentic reaches associated with the six hydropower impoundments on the lower mainstem (Lawler, Matusky, and Skelly Engineers 1991g). Purple loosestrife and Eurasian milfoil occur in some lakes and ponds within the watershed.

Fishery Management

High groundwater loading, cold summer stream temperatures, and stable flows are key ingredients for high-quality, self-sustaining salmonid fisheries. These ingredients are demonstrated in the many, valuable wild trout fisheries found throughout much of the Au Sable River system. Cold water riverine habitat represents the key value of the system, and long- and short-term management goals should focus on protecting and restoring such habitat. In addition, management activities should attempt to restore connections between fragmented aquatic habitats and restore more natural rates of water, sediment, and woody debris delivery to Lake Huron. Management should work toward restoring biological communities throughout the river system that are self-sustaining and require little more than protection from habitat degradation and over-exploitation.

Many impediments to achieving fishery goals exist. Fish communities typical of high-gradient, cold water, large river habitats have been reduced or eliminated in areas where such habitats have been altered or impounded (see **Biological Communities, Dams and Barriers**). Fragmentation of the river system has resulted in lost production of fishes, and reduced population levels of remnant fishes. Fish populations typical of natural lake outlets and habitats having gravel and rocky substrates have declined due to loss of these habitats. Short-term management activities need to address these problems while attempting to rehabilitate biological communities that are now impaired.

Given the recently issued FERC operating licenses (see Settlement Agreement in Appendix 1), the six Consumers Energy ponds may remain for at least an additional 35 years. Fishery management of these ponds should seek to maximize the potential of their fisheries given the constraints of these systems. Cool water temperatures and high flushing rates are the primary constraints to managing these systems for lake fishes. Temperature regulates metabolism, growth, and survival of fishes, and high flushing rates limit plankton production in the ponds and subsequent availability of food to fishes. For example, Kinney (1999) citing other authors provided the following optimal summer temperatures (in ^{o}F) for the sport fishes typical of Michigan lakes: walleye 68-75; yellow perch 68-82; northern pike 64-73; rock bass 69-78; smallmouth bass 70-81; largemouth bass 75-86; black crappie 68-82; bluegill 72-86; channel catfish 79-86; bullhead 68-86; white sucker 61-79; and carp 73-86. These values compare with the following average temperatures (in ^{o}F) for July 1990 at the outlets of the ponds: Mio- 68; Alcona- 70; Loud- 71; Five Channels- 71; Cooke- 72; and Foote- 72. Fishery management should target species whose preferred temperatures most closely match those observed in the ponds. However, management expectations need to be tempered with the understanding that summer temperatures of all ponds are on the lower end of the preference range for most of these fishes. As a result, most Michigan lake fishes may experience poorer growth during the summer and reduced over-winter survival. This results in populations that are less abundant than those in typical Michigan lakes.

Headwaters to Wakeley Bridge and North, South, and East branches Au Sable River

These streams support well-renowned fisheries for wild (self-sustaining) brook and brown trout (and rainbow trout in the mainstem). Fisheries Division has not stocked these reaches with brown or brook trout since the mid-1960s, with the exception of a few isolated stockings. Only two stockings of trout were reported for the mainstem upstream of Wakeley Bridge since 1965 (Figure 28). Stockings of rainbow trout for children's fishing events in Grayling are the only permitted trout stocking. Occasional un-permitted trout stockings have been known to occur throughout these waters.

Special regulations have been enacted to protect trout stocks and provide a high quality fishing experience in reaches of the mainstem, North, and South branches Au Sable River. Trout populations in these three streams have been monitored for several decades, with the set of population data being one of the longest in the country (see **Biological Communities**). Analyses of these data have been (and are) used to guide trout research and management throughout Michigan (Table 18). Concerns for these streams include: residential development in the riparian corridor and subsequent reduction in recruitment of large woody debris to streams; excessive sediment bedload; water quality degradation by Grayling Dam; increased runoff due to urban development in Grayling (Berry 1992); unnatural flow fluctuations due to operation of lake-level control structures; lost productivity due to fragmentation of reaches by dams; temperature elevation by beaver dams; and conflicts among user groups.

Declines in brown trout population levels in the mainstem and North Branch Au Sable River over the last decade have been a source of concern amongst anglers, citizens, and fishery biologists. The declines have resulted in increased pressure to stock these streams with trout. Stocking has been discouraged, in part because large numbers of young-of-year trout in population estimate data suggest adequate reproduction. Stocking fish entails a risk of introducing new diseases and parasites to streams. For example, whirling disease, which has devastated many western trout populations, was detected in the North Branch Au Sable River in 1995, and probably entered the river through un-permitted private trout stockings. There are ethical concerns of creating a dependency on hatchery fish (put-and-take fishery management) that conflicts long-term management goals of protecting the river's chief assets, in particular its ability to support self-sustaining populations of coldwater organisms, including trout. Others are concerned that stocking may compromise the genetic integrity of resident stocks.

Year-to-year survival of one and two year-old brown trout has declined in the mainstem and North Branch Au Sable River, indicating that other factors may be causing reductions in overall population levels. Declines have been attributed to reductions in the amount of cover provided by large woody debris and instream habitat structures. Though many habitat structures have been rebuilt, occurrence of natural deadfalls and logjams has declined due to residential development within the riparian corridor and clearing of the stream for recreational boating. Future surveys will help indicate the extent to which availability of instream habitat structures may have influenced trout survival. Protection of riparian corridors and contributions of large woody debris are needed to restore more natural levels of instream habitat diversity.

Resolving the issue of the Au Sable River's trout population trends highlights the need for a more comprehensive understanding of the factors influencing population fluctuations. Past studies of the Au Sable River focused on specific issues, such as the effects of fishing regulations and angling on trout populations. Population trends that developed over the course of these studies however, suggested that other factors (e.g. nutrient levels; see **Water Quality**) may over-ride the effects of angling. Ecosystem-level monitoring, which involves monitoring all important aspects of stream ecosystems (not just fish populations), is needed so that managers can better detect, diagnose, and treat fishery problems.

Wakeley Bridge to Mio Pond

This segment is managed primarily for trophy brown trout. It is primarily a boat fishery, the waters generally being too deep for wading except in a few areas. This reach has not been stocked with brown trout since 1964 (except for 1979) and relies on natural recruitment of browns from upstream reaches and tributaries (Figure 29). Modest numbers of rainbow trout (<10,000 fish/year) were stocked here until 1995, but were discontinued to allow resident stocks to develop. Large pike also inhabit slow velocity habitats, such as in the Stillwaters area, below the South Branch Au Sable River. Fishing pressure is intermediate between upstream and downstream reaches, and harvest is thought to be high but has not been documented. The reach has not been surveyed intensively, being too deep for wading and somewhat shallow for boat electrofishing. A 1992 fish survey at Parmalee Bridge showed white sucker, whitefish (probably round whitefish), and brown trout to be the most abundant species by weight. Fisheries and water temperature surveys throughout this segment are needed to better assess present fish communities and help target management. Creel census is also needed to document angling pressure and catch.

Mio Pond to McKinley Bridge

Mio Pond has somewhat limited fishery potential, mostly for coolwater fishes. Cool temperatures and a high flushing rate (<7 days) provide an environment somewhere between lotic and lentic. In general, reservoirs with high flushing rates, such as those on the lower mainstem, function more like rivers than lakes in regard to nutrient, plankton, and productivity cycles. Netting surveys of Mio Pond show a community dominated by coolwater fishes, with bowfin, white sucker, and northern pike comprising 60% of the biomass (Table 20). In an attempt to improve sport fish populations, a rough fish removal project conducted between 1979 and 1986, annually removed 1-9 lbs/acre of white suckers, bowfin, and carp. This project had limited success and was discontinued. Channel catfish were recently stocked here as a predator. Mio Pond has been stocked with rainbow trout, walleye, and yellow perch in the past (Table 17). Serns evaluations (used to assess success of walleye stocking or natural reproduction) of the 1993 walleye stocking collected 20.7 walleye <8 inches per mile of shoreline (Table 25); somewhat below the 40 fish/mi value that is typical of a "good" walleye lake (J. Schneider, MDNR, Fisheries Division, personal communication). Electrofishing and netting catches of larger walleye were also low relative to natural lakes (Table 26). However, this modest walleye population in the pond is successfully reproducing. Walleye abundance in Mio Pond may also be limited by entrainment mortality. In 1990, 13,775 walleye were killed in hydropower turbines, amounting to 16.0 walleye killed per surface acre of Mio Pond. For comparison, 58 lakes in Wisconsin had an average of 10.4 walleye per surface acre (Beard et al. 1997). Given Mio Pond's cool temperatures (July 1990 average temperature was 68 ^{o}F) sport fishes most suitable for management would be northern pike and white sucker, and to a lesser extent walleye, yellow perch, rock bass, black crappie, and bullhead. Submerged woody debris habitat is sparse in Mio Pond.

The mainstem is managed for "trophy" brown and rainbow trout from Mio Dam downstream to McKinley Bridge. Quality fishing regulations for trout have been in place in these 14.2 riverine miles since 1965. Influxes of groundwater along the reach provide thermal refugia for trout during the hottest periods of summer (see **Geology and Hydrology**). However, reproductive success of trout is poorer here than above Mio Pond. Consequently, this reach has received regular stockings of both brown and rainbow trout, being more heavily stocked in recent years (Figure 30). Warming of the river by Mio Pond is suspected to be impairing survival of naturally reproduced trout through the summer. Cooling of this reach by installing a bottom draw at Mio Dam could potentially improve conditions for growth and survival of stocked trout, and investigation into this is needed. Anchor ice associated with cold water being discharged below Mio Dam may also be damaging trout redds.

Fish communities in this riverine segment have not been surveyed, except in the short reach below Mio Dam. Limited data on the fish community here indicate more cool- and warmwater species, owing to the thermal effects of Mio Pond (see **Biological Communities**). Walleye numbers seem to be increasing due to stocking and natural reproduction. Walleye stocking was temporarily discontinued due to concerns of excessive predation on stocked trout (DePhilip 1997), but will resume since recent data has shown few walleye in riverine habitats. Fishing pressure is thought to be somewhat lower in the Mio to McKinley stretch than in upstream reaches. However, increased stocking rates have led to dramatic increases in fishing pressure. Fish community, creel, and temperature surveys are needed along this segment.

Mio Dam is the primary impediment to management of this segment as a free-flowing, cold water river. The dam fragments the river, elevates water temperatures (see **Dams and Barriers, Water Quality**), and impounds rare, high-gradient river habitat (see **Channel Morphology**). Estimates from 1991 suggest that Mio Dam turbines entrain roughly 120,000 fish and kill about 30,000 fish annually. Annual losses range between roughly $91,000 and $297,000 (Table 7). If Mio Dam was not present, this 9.4 mile river reach has the potential to annually provide benefits from riverine trout fishing and natural reproduction of riffle-spawning fishes. Moderate to high-gradient conditions in this reach would provide excellent hydraulic diversity for riverine fishes with fast rapids and regular riffle-pool sequences. These estimates do not include additional benefits for other cold- and cool-water riverine species that use these habitats, including sport fishes such as whitefishes, other salmonids, and walleye. Dam removal would cool summer temperatures in downstream reaches, improving their suitability for salmonid reproduction and survival.

McKinley Bridge to Five Channels Dam

The mainstem from McKinley Bridge to Alcona Pond is managed for trophy trout, though there are no special regulations. This reach has been stocked annually for several decades, with increased stockings in recent years (Figure 31). Fishing pressure is somewhat lighter in this reach. Instream habitat conditions in riverine reaches between McKinley Bridge and Alcona Pond are considered good, with fairly high gradients, coarse substrates, and deep pools formed by the river. However, large woody debris is limited due to past logging and dam operations (see **Dams and Barriers**). Sites that used to add sediment to the stream have largely been treated.

Alcona Pond, like Mio Pond, is managed for coolwater fishes. Potential of this pond for production of lentic fishes is limited by its cool summer temperatures and short retention time of < 6 days (FERC 1994). Low-velocity, coolwater fishes were most abundant in recent netting surveys (Table 20). Most abundant species by weight were white sucker, bowfin, smallmouth bass, rock bass, and brown bullhead. Production of young-of-year walleye seemed to have been more successful here than in other lower mainstem impoundments based on Serns index surveys (Table 25). Small walleye collected during the 1995 survey were either naturally produced or from upstream stockings because Alcona Pond was not stocked that year. Still, catches of larger fish by netting and electrofishing indicate walleye populations lower than those found in other natural lakes in the area (Table 26). Walleye stocking was temporarily discontinued due to concerns of excessive predation on stocked trout (DePhilip 1997), but will resume since recent data has shown few walleye in riverine habitats. Entrainment mortality of walleye may also be limiting population. For example, 6980 walleye were killed in 1990, which amounted to 6.5 fish per surface acre. Given Alcona Pond's summer temperatures (July 1990 average temperature was 70 ^{o}F) sport fishes most suitable for management would be northern pike, walleye, yellow perch, rock bass, black crappie, bullhead, and white sucker, and to a lesser extent smallmouth bass. Submerged woody debris habitat is sparse in Alcona Pond.

The short riverine reach between Alcona Dam and Loud Pond is also managed for large trout. This reach has been stocked annually for several decades, with increased stockings recently (Figure 31). However, stream temperatures here are considerably higher than those above Alcona Pond, and are impairing trout survival (Figure 15). Cooling of this reach by installing a bottom draw at Alcona Dam would improve conditions for growth and survival of stocked trout.

Alcona Pond affects the lower mainstem in other ways. Estimates from 1991 show over 89,000 fish are entrained and more than 19,000 fish are killed, with a restitution value ranging between $30,000-

$173,000 (Table 7). Fragmentation reduces fish population levels and production of riverine species (see **Dams and Barriers**). Alcona Dam impounds some of the very rare, 10+ ft/mi gradient reaches of the lower mainstem, eliminating these riverine habitats. The 8.1 miles of river impounded by the dam have the potential to annually provide benefits from resident trout fishing, potamodromous fishing (if Lake Huron fishes had access), and production of Great Lakes salmonids now being stocked by the Fisheries Division (Table 8). Other species, including sport fishes such as lake sturgeon, whitefishes, other salmonids, walleye, and smallmouth bass, would benefit from the newly available, cobble-boulder dominated rapids and riffle-pool habitats. Summer stream temperatures would be reduced, restoring additional miles of cold water habitat further downstream.

Loud and Five Channels ponds are both small and have high flushing rates. The flushing rate for Loud Pond is less than 3 days and that for Five Channels is less than 2 days (FERC 1994). Fish communities are typical of slow, cool-warm rivers, with suckers, bowfin, and bullheads comprising 84% and 64% by weight of the survey catches in Loud and Five Channels ponds (Table 20). Attempts to establish self-sustaining walleye populations have largely failed, and walleye were low in survey catches. Despite the limited fishery, Loud and Five Channels dams exact a considerable toll on present fish communities. These dams are estimated to entrain more than 589,000 fish per year and kill an estimated 95,000 fish annually (Table 7). The value of these annual losses ranges between $94,000 and $785,000. Given the summer temperatures for Loud and Five Channels ponds (both averaged 71 ^{o}F in July 1990) sport fishes most suitable for management would be northern pike, walleye, yellow perch, rock bass, smallmouth bass, black crappie, bullhead, and white sucker. However, the extremely high flushing rates of these ponds limits management for these species. Surveys of submerged structural habitat are needed in both ponds.

This reach has high fisheries potential if these dams were removed. Loud and Five Channels dams impound the longest, continuously high-gradient reach on the lower mainstem, including rapids having 12+ ft/mi gradient (see **Channel Morphology**). Shorelines of both impoundments are undeveloped and owned by the U.S. Forest Service and Consumers Energy. Without dams, this reach could provide spectacular riverine fishing and recreation in a wilderness (limited access) environment. Fisheries benefits would include natural production of an estimated 408,100 chinook smolts and 132,055 steelhead smolts (Table 8). These high-gradient waters would be especially valuable for lake sturgeon, which spawn in boulder and cobble-dominated rapids. We estimated that this reach could support adult lake sturgeon runs of more than 14,000 fish and a substantial population of resident fish (Table 8). These 10.9 miles of river have the potential to benefit many additional cold- and cool-water, river-resident fishes including brown trout, walleye, smallmouth bass, whitefishes, and several species of redhorse and sucker.

Five Channels Dam to Foote Dam

This segment consists of Cooke and Foote ponds. Both ponds cover fairly low gradient reaches of the mainstem, and like the other ponds have short retention times (<11 days for both ponds). These two ponds are also cool, but are the warmest of the series of ponds, being furthest downstream and warmed by upstream ponds. Fish communities in 1996 reflected this with greater representation of largemouth bass, smallmouth bass, and sunfishes in survey data (Table 20). Tiger muskellunge were stocked into both impoundments in an attempt to reduce redhorse, white sucker, and carp populations, but stockings were unsuccessful and have been abandoned. Given the summer temperatures for Cooke and Foote ponds (both averaged 72 ^{o}F in July 1990) sport fishes most suitable for management would be northern pike, walleye, yellow perch, rock bass, smallmouth bass, black crappie, bullhead, and white sucker, and to a lesser extent bluegill. Surveys of submerged structural habitat are needed in both ponds.

The river reaches beneath these ponds have especially high potential for production of potamodromous fishes due to their close proximity to Lake Huron. In their present state, these ponds are estimated to annually entrain more than 376,000 fish and kill more than 85,000 fish; estimated restitution values range from $181,000 to more than $1,226,000 (Table 7). More importantly, they sever the migratory connection between the Au Sable River and Lake Huron, resulting in lost production of large-bodied, valuable fishes that use Lake Huron or large, cool river habitats. Species would include chinook and coho salmon, steelhead, brown trout, lake sturgeon, walleye, whitefishes, channel catfish, burbot, and various redhorse and sucker species. Areas of moderate gradient (>3 ft/mi) exist that could potentially support substantial natural populations of chinook salmon, steelhead, walleye, and other species that use riffle-pool and run habitats. Summer temperatures here may be too high for year-to-year survival of resident salmonids and steelhead parr, though tributaries may be used. Given temperature conditions for adequate survival, these reaches were estimated to be capable of producing 408,100 chinook smolts and 132,055 steelhead smolts (Table 8). Given the value of the potamodromous fishery below Foote Dam, these reaches would also undoubtedly support valuable sport fisheries for potamodromous species. Additional low-gradient, riverine habitat also has the potential to benefit the state-threatened channel darter (see **Biological Communities**).

Foote Dam to Lake Huron

Only these 10.2 miles of the mainstem's 152+ miles are connected with Lake Huron. Potamodromous fishing opportunities are numerous owing to this feature. Major stream fisheries exist for steelhead, chinook salmon, and walleye. Other sport fish of importance include channel catfish, brown trout, smallmouth bass, and rainbow smelt. A 1987 creel census conducted in this reach estimated that anglers spent 33,599 days catching 7,416 chinook salmon, 5,081 rainbow trout (steelhead), 8,952 channel catfish, 153 brown trout, 810 walleye and 4 coho salmon (Rakoczy and Rogers 1988). At a value of $54 per angler day (United States Department of Interior, Fish and Wildlife Service and United States Department of Commerce, Bureau of Census, 1991), the value of potamodromous fishery in 1987 was worth $1,814,346. This equates to $177,877 per mile for the 10.2 miles of this reach.

Management has focused on stocking salmonids to produce a fishery in Lake Huron and the potamodromous fishery in the river. The reach is classified as "second quality trout water" due to effects of upstream dams on water quality. Natural reproduction of salmonids is mostly limited to chinook salmon whose young leave the river before the warmest summer months. Stockings of chinook and coho salmon, various strains of winter and summer steelhead, lake trout, and Atlantic salmon were made in the 1970s and 80s with varying degrees of success (Figure 32). Coho and Atlantic salmon stockings failed to produce significant fisheries. Chinook and winter steelhead are now the mainstay of the sport fishery with minor contributions from summer steelhead and brown trout. Steelhead and chinook salmon stockings have averaged 150,000 (steelhead) and 500,000 (chinook) in recent years. Potamodromous runs of walleye and channel catfish have also been increasing in recent years primarily due to straying from expanding populations in Saginaw Bay. Upstream stockings of walleye are also a possible source for the river's increased walleye run. Sitings of lake sturgeon in this segment have been reported periodically, the latest being a June 1996 report of a pair of fish spawning below Foote Dam.

The Pine River is of importance for both the fishery in Van Etten Lake and for its contribution to the Lake Huron fishery. Van Etten Lake is now stocked with walleye. It is suspected that most of the natural recruitment of Great Lakes salmonids in the Au Sable River comes from the Pine River system (J. Johnson, MDNR, Fisheries Division, personal communication). However, migration of fishes through Van Etten Lake is limited by the lack of a structure specifically designed for passing fish through the lake-level control structure.

Potential for Improvements to Sport Fisheries

Sport fisheries for trout throughout the river system would benefit from a variety of actions. Protection and restoration of natural streamflow patterns would aid in preventing fish recruitment problems resulting from flood events. Removal of impoundments in trout waters would help restore cold water habitats in impounded reaches and areas further downstream. Reductions in sediment erosion from upland areas, stream banks, and at road-stream crossings, and removal of excessive sand bedload, would help restore and maintain gravel habitats critical to stream fishes and other aquatic organisms. Removal of dams on small tributary streams would help restore cooler stream temperatures and natural daily temperature variation, allow greater movement of fish between higher quality habitats within the system, and enable natural recolonization of habitats after disturbance. Removals of lake-level control structures would benefit aquatic communities (and sport fishes such as northern pike) by restoring lake outlet wetlands and wetlands associated with natural water level fluctuations.

Several improvements could be made at hydroelectric dams to lessen their effects on the river system. Screens on turbine intakes would reduce fish entrainment and mortality. Physical modifications to dams could improve downstream water quality and lower temperatures. Fish ladders would allow for more natural migrations of fishes, improve productivity of upstream and downstream reaches, and increase the resiliency of populations to disturbance and long-term changes in stream environments. Intermingling of isolated stocks may also improve the genetic viability of fish populations. Dam removal would more adequately provide all these benefits in addition to: restoring rare, high-gradient reaches; providing natural downstream transport of woody debris and sediment; restoring lost floodplain habitat; allowing natural upstream and downstream movement of aquatic species; providing upstream transport of nutrients in the form of fish gametes and carcasses; and increasing productivity of the entire system.

There is tremendous potential for expanding potamodromous fisheries and riverine fisheries within the river system. Only about 7% of the mainstem and none of its tributaries (with the exception of the Pine River) are connected to Lake Huron. Au Sable River provides some of the best cold water riverine habitat in the state; habitat that is not being fully used. Au Sable River below Mio Dam alone has the potential to provide the full complement of chinook salmon and steelhead needed to annually supply Lake Huron (given adequate survival of out-migrating smolts), eliminating the lake's dependency on hatchery-reared fish. The potamodromous sport fisheries produced would undoubtedly be of great value. For example, the potamodromous fishery in 10.2 miles below Foote Dam supported an average of 32,310 angler days per year and had an estimated annual value of $1,744,763 between 1987-1989 (Rakoczy and Rogers 1987; Rakoczy and Rogers 1988; Rakoczy and Rogers 1990). An additional 82 river miles lie between Foote and Mio Dams.

A considerable amount of this lost fish production and recreational fishery value could be recovered by providing fish passage to remaining riverine sections of the river. For example, about 10 million June chinook smolts could be produced in presently existing, riverine reaches below Mio Dam (Table 8). Given adequate survival of out-migrating smolts, this could satisfy the annual stocking needs of Lake Huron. However, elevated stream temperatures and downstream dams may cause mortality of fishes to the extent that the species may still need to be stocked into Lake Huron.

Fish passage will benefit other fishes in addition to those discussed above. Many species of fish formerly ran considerable distances up the river, including lake sturgeon, walleye, round whitefish, and suckers (see **Biological Communities**). Gametes and carcasses left in upstream reaches by these and other species would provide important sources of nutrients for riverine fishes and other species living in upstream, relatively nutrient-poor reaches. These nutrients would increase growth of resident fishes and increase overall productivity of the system (Bilby et al. 1998).

The potential recreational and fish production benefits of dam removal or fish passage need to be weighed against the value of the existing fishery and costs for dam removal or fish passage devices. The value of the existing fishery between Mio Pond and Foote Dam is unknown and needs to be estimated. Four fish passage structures would be required to open the Alcona to Loud reach to Great Lakes fishes. An additional fish passage structure would be needed to pass into the Mio to Alcona reach; another ladder would be needed to provide fishes access to the river above Mio. Costs of fish passage devices would range from about $480,000 for trap and transfer to $1,600,000 for fish ladder construction at each dam (based on estimates for Tippy Dam on the Manistee River, Consumers Power Company 1991). Combined construction costs for fish ladders at the first four dams would range from $1,920,000 to $6,400,000. Costs for fish ladders at the remaining two dams would be from $960,000 to $3,200,000. As per terms of the Settlement Agreement, Consumers Energy would provide for the design, construction, operation, and maintenance of fish passage structures at the six Consumers Energy dams on the river (Appendix 1). Fish ladders typically have higher construction costs, but lower maintenance costs, than trap and transfer. However, once constructed, fish ladders can pass fishes year-round for many years with minimal maintenance cost. In addition, they require less “hands-on” upkeep, in terms of logistical coordination and expense, than trap and transfer. Given the value of existing potamodromous fisheries on the lower mainstem, the amount of time to recover costs of ladder construction may not be long.

Some Economic Trade-offs of Removing Dams on the Au Sable River

Both economic costs and benefits would be associated with removing Consumers Energy dams on the Au Sable River. The following lists some of the economic benefits associated with the Consumers Energy projects on the river, and contrasts those with some of the potential economic benefits of dam removal.

In 1990, the Consumers Energy projects contributed $2,402,683 to the economies of local communities. Property taxes paid to the counties with the six Consumers Energy projects totaled $773,125 in 1990 (FERC 1994). These property taxes composed the following percentages of 1990 total tax revenues for counties containing Consumers Energy projects: Oscoda-2.1%; Alcona-2.1%; and Iosco-2.4% (Oscoda, Alcona, and Iosco county equalization departments, personal communication). Local subcontractors received $630,100 and Consumers Energy employees were paid $560,005 in 1990 (FERC 1994). The 1990 estimated total value of recreation on Consumers Energy project lands was estimated at $560,005 (FERC 1994). The value of existing fisheries in lower mainstem upstream of Foote Dam is unknown (though thought to be modest), and needs to be quantified. Likewise, economic benefits of other types of recreation on the ponds need to be quantified. The projected 30-year average annual profit to Consumers Energy for producing power from the six dams is $6,897,000 (FERC 1994). This probably represents the maximum amount of revenue that could be taxed by the State of Michigan, and does not go directly to local communities.

Removal of dams could result in significant economic benefits to communities along the lower Au Sable River. In addition, benefits would be spread over a longer season than the typical summer tourist season. Removal of dams would result in valuable spring and fall fisheries for potamodromous fishes, and an improved resident trout fishery (due to cooler water temperatures and uncovering of high-quality habitat). Much of the value of the fisheries would accrue to businesses in local communities, such as motels, restaurants, sporting goods shops, and guiding services. Production of potamodromous fishes that MDNR Fisheries Division now stocks represents an economic savings (hence benefit) to the State of Michigan and its anglers. In addition, considerable recreational canoeing use would be expected during the summer. Use of waterfront parklands could also continue after dam removal, though the type and level of use would potentially change.

Considerations Regarding Upstream Passage of Great Lakes Fishes

Passing Great Lakes fishes into the upper portions of the Au Sable River has the potential to re-establish spawning runs of native (lake sturgeon, walleye, whitefish, suckers) and naturalized (chinook salmon, coho salmon, steelhead, brown trout) fishes, and restore self-sustaining fish populations in the river and Lake Huron. Substantial fishery, recreational, and economic benefits would result from these spawning runs. Some of these fishes, however, contain elevated levels of chemical contaminants in their tissues that would be introduced into upstream reaches as fish spawned and died. These chemicals are essentially absent in fishes from the Au Sable River above Foote Dam. The effects of these introduced chemicals on animals co-inhabiting upstream reaches has been a cause of concern. Bioaccumulation of these chemicals could lead to adverse effects on populations of fish-eating carnivores, such as bald eagle, cormorant, osprey, great blue heron, kingfisher, mink, and river otter.

High concentrations of specific contaminants, such as PCBs and other polychlorinated hydrocarbons, in fish and other aquatic prey, such as gulls, can have chronic effects on reproduction and health of carnivores, including bald eagles, mink, and river otter (Ludwig et al. 1993). Dioxins, dieldrin, PCBs, and DDE are the primary contaminants that affect bird reproduction and PCBs are the primary contaminants affecting mink and river otter. PCB concentrations in Lake Huron fish have declined since the early 1980s and are at low (relative to the other Great Lakes), stable levels (Figure 18; Day 1997). Effects of declining contaminant levels are also apparent in fish eating birds. Double-crested cormorant population levels have increased an average of 29% per year over the last 20 years (Ewins 1994). Eagle populations have also rebounded dramatically. The number of breeding pairs in Michigan has increased from 87 in 1977 to 273 in 1996 (J. Weinrich, MDNR, Wildlife Division, unpublished data). The Northern States Bald Eagle Recovery Plan set a recovery goal of 140 nesting pairs in Michigan with an average production of at least 1.0 fledglings per occupied nest (Sprunt et al. 1973). The 140 nesting pair criteria was surpassed in 1987, and the 1.0 young per nest value has been nearly achieved (1992-1996 mean productivity = 0.99 fledglings per occupied nest; T. Weise, MDNR, Wildlife Division, unpublished data). Bowerman et al. (1995) noted that the percent increase in bald eagle nesting areas between 1977 and 1993 was faster along the Great Lakes than in inland areas (Figure 33). The rate of increase for all types of nesting areas would be expected to level off through time as eagle pairs occupy the limited number of suitable areas. Productivity of Great Lakes shoreline and anadromous (within 5 miles of the shoreline) nesting eagles increased during this period while that of inland eagles remained relatively unchanged (Figure 34). Sprunt et al. (1973) mentioned that stable eagle populations require a productivity rate of 0.70 fledglings per occupied nest, and healthy populations require a productivity rate of 1.00 fledglings per occupied nest. For the 5-year period from 1992-1996, Lower Peninsula eagles had productivity rates of: anadromous- 0.97; Great Lakes- 0.80; and inland- 1.20 (T. Weise, MDNR, Wildlife Division, unpublished data). Using the criteria of Sprunt et al. (1973), the productivity data for the Lower Peninsula eagles suggests that anadromous eagles are “healthy” and that Great Lakes eagles are at least “stable” and approaching “healthy”. The increased productivity of Great Lakes eagles is especially notable because, in addition to eating potamodromous fishes, Great Lakes eagles forage on a higher percentage of aquatic-feeding birds, such as waterfowl, gulls, and colonial waterbirds, that are known to contain even higher contaminant levels than Great Lakes fishes (Sprunt et al. 1973).

Food quantity has been identified as the most important factor limiting eaglet production (Stalmaster and Gessamen 1984). Increased fish runs due to fish passage or dam removal may increase eagle productivity by making more forage available (Bowerman and Giesy 1991). Eaglet production from nests along Lake Michigan streams with anadromous fish runs support this statement. Between 1989 and 1994, anadromous eagles nests on the Pere Marquette River (Pere Marquette River nest) and Manistee River (Wellston nest) had annual productivity rates of 1.67 and 1.83 fledglings per occupied nest (Rozich 1998). In addition, dam removal would make more ice-free, large river habitat available for eagle foraging. This habitat-type is important to over-wintering eagles, but is now limited in the Au Sable River system (Bowerman and Giesy 1991; Martell 1992). In summary, this information indicates that passage of fish or dam removal would have little if any adverse effect on bald eagle productivity, and may even benefit the species.

A causal link between the status of mink and otter populations and exposure to organochlorine chemicals in the Great Lakes has not yet been established (Wren 1991). However, laboratory experiments have shown that mink are extremely sensitive to organochlorine chemicals, particularly PCBs and dioxins (Giesy et al. 1994a). Ranch mink being fed contaminant-laden carp from Lake Huron showed impaired reproductive success, liver damage, and hematological effects (Heaton et al. 1995a; Heaton et al. 1995b). Heaton et al's Hazard Index (HI) study findings should be carefully interpreted when addressing fish passage issues on the Au Sable River for several reasons: 1) they assumed a mink's daily diet consisted solely of one species of fish though actual diets are much more diverse; 2) a fish species was considered hazardous (HI>1) when, as the sole item in the mink's diet, it caused a mink to exceed the maximum allowable daily intake (MADI) of PCBs; 3) use of a safety factor of 10 in calculating MADI values caused many fish to become unsafe; without it, all fishes tested for Lake Huron (except the most contaminated carp) would have been considered safe for consumption (HI<1); 4)Great Lakes fish would mainly be available for about half the year; and 5)carp, the most highly contaminated Lake Huron fish, would probably make up an extremely minor portion of riverine mink diets because carp are rarely in high-velocity, cold water riverine habitats (significant carp populations only exist in lower mainstem impoundments) and would not be expected to use fish ladders. Using a safety factor of 10, Giesy et al. (1994a) estimated that fishes below Foote Dam could compose roughly 30% of a mink's diet before PCB hazard index values were exceeded (HI>1). He noted that PCB levels in Lake Huron fishes were less hazardous than Lake Michigan fishes, but suggested that mink could potentially receive acute doses of PCBs if they foraged heavily on dying chinook and coho salmon during spawning runs. Information for comparing Great Lakes influenced and inland mink populations in Michigan is lacking and there are no ongoing population studies. However, mink populations are assumed to be stable and at healthy levels. Harvest regulations for mink have not changed for many years and there is no bag limit.

The effect of Great Lakes fish migrations on river otter populations has not been studied in detail. However, several observations suggest that a diet containing Great Lakes fishes may be only one of several factors influencing otter distributions. Predictors of otter presence in Lower Michigan streams included fish PCB levels, limited prey availability due to low summer streamflows, and the percentages of urban and agricultural land use within the riparian corridor (Kotanchik 1997). Interestingly, Kotanchik (1997) identified a reach of the Rifle River, a stream open to potamodromous runs, as one of two stream segments in the Lower Peninsula having the highest otter density. Her data also showed a river otter density in the Pine River (an Au Sable River tributary open to Great Lakes fish migrations) comparable to otter densities in much of the Au Sable River. O'Neal (1997) noted that sections of the White River (open to Great Lakes fish migrations) were open to otter trapping, while upstream reaches closed to Great Lakes fish migrations were closed to trapping. Wren (1991) observed that otter harvest in Michigan gradually increased during the 1950s, and was fairly level during the 1970s and 1980s. River otter harvest from 1985 to 1995 has ranged between 654 to 1551 with no clear temporal trend (O'Neal 1997). However, river otter harvest is not a good indicator of population abundance because it varies with fur prices and beaver trapping pressure. The recent increase from 2 to 3 in Michigan's season bag limit for river otter suggests that Michigan populations are stable or increasing. Harvest of river otter is permitted within the entire Au Sable River watershed.

Despite the decreases in organochlorine contaminants, significant increases in eagle and other avian populations, and apparent increases in river otter populations in Michigan, there is still concern that contaminant levels in Great Lakes fish may be affecting wildlife populations. Contaminant hazard assessment studies were sponsored by Consumers Energy during hydroelectric dam relicensing procedures, and were summarized by Ecological Research Services, Inc. (1991), Bowerman and Giesy (1991), Giesy et al. (1994a), Giesy et al. (1994b), and Giesy et al. (1995). Effects of different contaminant levels in surrogate birds and ranch mink were used to predict contaminant levels at which the species of interest might be impaired. Wood duck (*Aix sponsa*), herring gull (*Larus argentatus*) and domestic chickens were used as surrogate species for the bald eagle. Contaminant levels in certain species of fish, along with many assumptions related to biomagnification, bioassay (cormorant blood plasma and cultured rat cellular enzymes), and estimated mercury, PCBs, DDT, DDE, and dieldrin chemical equivalence factors (dioxins or dioxin equivalents) were used to predict contaminant levels in eagles and mink. The value of some surrogate measures of contaminant concentrations in making inferences regarding reproductive success of animals has also been questioned, because of weak or non-existent relations between such measures and actual data on reproductive success. For example, Bowerman et al. (1998) found no trends in PCBs or DDE levels in eggs of bald eagles nesting along the Great Lakes, even though a very clear increase in reproductive success was observed during this time period. Hazard assessments incorporated safety factors, but not statistical uncertainty factors that may often be needed. For example, Johnson et al. (1996) noted that predatory fish did not biomagnify dioxins in the field, even though laboratory studies documented biomagnification of dioxins by fish. Various factors, including lipid levels, metabolism, site-specific transport effects, and food choice, make trophic transfer more complicated than previously thought (Johnson et al. 1996).

Studies of transport of organic contaminants into upstream areas by migrating fish indicate that the fate of contaminants appears to be limited to organisms that directly ingest contaminated eggs and fish flesh. In a study of Manistee and Muskegon river tributaries, Merna (1986) observed elevated PCB and DDT levels in brown trout and sculpins, which ate Lake Michigan salmon eggs, but could not detect elevated concentrations of contaminants in crayfish, and sand and organic sediments. He also looked for elevated dieldrin levels, but could not find them in either biota or sediment samples. Brown trout and blowfly larvae feeding on salmon eggs or flesh in Lake Ontario tributaries had elevated mirex levels, but crayfish, stoneflies, and sediments from the same locations did not (Scrudato and McDowell 1989). Johnson et al. (1996) found that fishes upstream of dioxin-contaminated site were contaminated, but sediment was not. However, fish contamination at the contamination site was attributed to uptake from sediments and through the food chain. Potential increases in contaminant loads of animals feeding on eggs and carcasses of Great Lakes fishes represents a trade-off against increases in growth of individuals and productivity of populations (Bilby et al. 1998; Stalmaster and Gessamen 1984) and the system as a whole.

Sea lamprey would have to be blocked from the Au Sable River above Foote Dam if fish passage structures were built or dams were removed. O'Neal (1997) cited $200,000 as the current cost for installation of the electric barrier on the Pere Marquette River. The cost of such a barrier at the mouth of the Au Sable River would be higher because of the river's larger size. Properly designed fish passage structures at the Foote Dam site and the Van Etten Lake level control structure could prevent sea lamprey from accessing all cold water riverine habitats in the watershed. Again, Consumers Energy has agreed to bear the costs for fish passage at their dams on the river (Appendix 1).

Whirling disease spores are in portions of the river upstream of Mio Dam (see **Biological Communities**). Passage of Great Lakes fishes into riverine reaches on the lower mainstem upstream of dams could result in whirling disease infections of species, such steelhead. However, such infections may not happen because relatively abundant populations of both whirling disease hosts (fish and *Tubifex tubifex*) must also be in the river. If steelhead are passed upstream, their offspring should be monitored to determine if whirling disease is a problem.

Potamodromous fish passage into the river above Mio Dam is not an option because of the self-sustaining, brook trout and brown trout populations and world-renowned fisheries they support. Portions of the upper mainstem, North, and South branches of the Au Sable River are managed as "artificial flies-only" and have restrictive minimum size and creel limits. These waters draw anglers from throughout the United States. Many organized angling groups (see **Citizen Involvement**) have a strong interest in protecting this portion of the river and its fisheries.

Many social issues may dictate fish passage on the lower mainstem. The primary social issue involves conflicts between riparian residents and anglers, because potamodromous fish will probably attract more anglers. On private property, trespassing, littering, illegal angling, and other problems may occur. The federal and state governments, and Consumers Energy own most of the riparian land along portions of the lower mainstem that would be opened to potamodromous runs. Their ability to control access to the lower mainstem provides fair degree of control over these problems. In addition, larger rivers can more readily accommodate greater angling pressure. The potential for riparian conflict is greater further upstream of Mio where riparian ownership is largely private. Rozich (1998) suggested that any fish passage plans need to address: species and numbers of fish to be passed; the ability of the stream to accommodate increased angling, availability of public access and parking sites; and law enforcement needs.

In summary, a potential fishery management goal for the Au Sable River is rehabilitation of spawning runs of native and naturalized fishes in the river above Consumers Energy dams and rehabilitation of lost productivity of fish populations in the river by providing fish passage or removing dams. Reaches now fragmented have the potential to support economically valuable sport fisheries, and would help restore self-sustaining salmonid populations to Lake Huron. The effect of fish passage on other species needs to be considered in further detail. Studies of bald eagle, a species known to bioaccumulate substantial amounts of organochlorine contaminants due to their diet of aquatic birds and fishes, indicate that nesting pairs along potamodromous streams in Michigan show reproductive success similar to (and sometimes greater than) their counterparts that do not forage on potamodromous fishes. Populations of bald eagles and other fish-eating waterbirds in the Great Lakes, such as cormorants, have increased dramatically in the last 15 years. Harvest regulations for mink and river otter, species somewhat lower on the food chain than bald eagles, do not indicate that significant reproductive effects would occur. Limited data on river otter indicate that their populations are increasing, as supported by the 1996 increase in the Michigan bag limit, and show high population levels on streams known to have runs of Great Lakes fishes. Potential increases in contaminant loads of animals feeding on eggs and carcasses of Great Lakes fishes would be traded-off against increased productivity of their populations, and the system as a whole. Substantial public and corporate ownership along the lower mainstem would help minimize the potential number of riparian conflicts in this portion of the river; social issues would be of greater importance upstream of Mio.

Recreational Use

The Au Sable River offers tremendous outdoor recreation opportunities due to the high quality of the resource, and considerable public and corporate ownership in the watershed. Important water-related recreational opportunities include angling, canoeing, boating, hunting, trapping, camping, nature study, and bird watching. Access to the river is widespread, provided by state, federal, municipal, and Consumers Energy lands (Figure 35). Additional access to the river from Consumers Energy lands is being added in compliance with the operating licenses recently issued to the projects (Appendix 1).

In addition to formal access points, there are many public-owned informal access points. Improvements are needed at heavily used small-scale access sites to minimize their effects on the river.

Due to its importance as a study river (Table 18), angling and canoe use has been documented more frequently on the Au Sable River than other Michigan rivers. We summarized angling and canoe use for characterizing reaches that support major coldwater fisheries (Table 27). Updated estimates of recreational angling, canoeing, and boating use are needed for the entire river system, including its impoundments.

Canoeing is very popular in the Au Sable River watershed. Twenty-one canoe rental businesses operated on Natural River designated portions of the Au Sable River as of 1997 (Table 28). The number of commercial canoes registered at commercial liveries for use on these portions of the river has grown beyond the upper limit recommended in the Au Sable River Natural Rivers Plan (Anonymous 1987). Between 1992 and 1997, the number of canoes registered for such use went from 1676 to 1866, a 10% increase. To protect the river from overuse, effort is needed to achieve compliance with commercial watercraft limits set forth in the Au Sable River Natural Rivers Plan (Anonymous 1987).

Headwaters to Wakeley Bridge

The headwaters of the mainstem above the village of Frederic include two lake outlet tributaries, Bradford and Kolke creeks. The upper reaches of these tributaries provide limited angling opportunities for sunfish, largemouth bass, and northern pike for a relatively short distance. From the confluence of Bradford and Kolke creeks to the city of Grayling, groundwater inflows cause the warmwater fish communities in upstream reaches to be replaced by coldwater fishes downstream (Figure 8). The river from Frederic to Grayling is about 10-30 ft wide and wadable. It provides limited canoeing due to its small size, limited access, and numerous logjams. However, good angling opportunities occur here for brook trout and brown trout. This section is a designated Blue Ribbon Trout Stream. Land ownership is split between private and state ownership with walk-in access available at undeveloped locations. One impoundment (Grayling Millpond) is located in the city of Grayling and provides very limited opportunities for angling and canoeing.

Between Grayling and Wakeley Bridge, the mainstem roughly doubles in size, ranging from 50-100 ft in width. This reach provides the primary wading trout fishery on the mainstem, and includes the Au Sable River's "Holy Waters", a reach between Burton's Landing and Wakeley Bridge. The quality and popularity of this reach has made the Au Sable River one of the most well-known trout streams in the eastern United States. Ninety-three percent of the anglers fishing this reach are from outside of Crawford County, with 76% being from other counties in Michigan, and 18% from other states and Canada (Gigliotti 1989). Anglers may only fish this stretch using artificial flies and no trout may be kept. The Burton's Landing to Wakeley Bridge stretch supports the highest angling use and brown trout catches, when compared to the North and South branches of the Au Sable River (Table 27). From 1960-1983, the Burton's Landing to Wakeley Bridge reach received an annual average of 4380 hours/mi of angling and 7000 hours/mi of canoe use. Annual brown and brook trout catches averaged 700 and 150 fish/mi respectively. Angling and canoeing use generally increased here during the 1970s and 1980s (Table 27), and is thought to still be at relatively high levels. Canoe use is heavier on the Grayling to Burton's Landing reach than the Burton's Landing to Wakeley Bridge stretch (yearly average of 11600 vs. 7000 hrs/mi), probably because the former is closer to Grayling. Conflicts between anglers, canoeists, and riparian landowners occur on the river between Grayling and Wakeley Bridge.

Wakeley Bridge to Mio Pond

The river grows considerably in size here as it receives the North and South branches of the Au Sable River and Big Creek-South. This segment is 60-140 ft wide, has moderate gradient, and is somewhat wadable, but mostly provides a float fishery due to deep water. The fishery is mostly for brook, brown, and rainbow trout. The segment receives less canoeing use than the Headwaters to Wakeley segment, because it is more than a day's float from the Grayling canoe liveries.

Mio Pond to McKinley Bridge

Mio Pond provides fair fishing for coolwater fishes such as: northern pike, walleye, smallmouth bass, rock bass, and yellow perch. Recreational boat and canoe use take place on the pond, though pressure is considered light. Below Mio Dam, the river supports heavy canoe (and tubing) use. Watercraft use between Mio Dam and Alcona Pond was estimated at 27,342 trips in 1984 and 25,379 trips in 1994 (Johnson and Nelson 1996). This equates to 8000-9000 hours/mi if one assumes it takes 7 hours to cover the 22 mi trip. This level of use is comparable that of the mainstem between Grayling and Wakeley Bridge (8800 hrs/mi). There is a moderate amount of angling, primarily for stocked brown and rainbow trout. The larger size of the river better accommodates anglers and canoeists, lessening conflicts between these user groups. Quality trout fishing regulations are in place from 0.25 mi below Mio Dam to McKinley Bridge. Anglers occasionally catch walleye. The river in this segment ranges between 130-170 ft in width. Mio Pond covers high-gradient habitat (Table 3) that would provide valuable riverine habitat for angling and canoeing (see **Fishery Management**).

McKinley Bridge to Five Channels Dam

Being more than a typical day's float from Mio, this segment receives less angling and canoe use than the upstream segment. However, it still provides a stocked brown and rainbow trout fishery, and provides medium- to high-gradient waters for canoeists. The river is somewhat larger than the upstream segment, ranging from 140-180 feet wide. Alcona Pond provides a popular fishery for walleye, smallmouth bass, and northern pike, due in part to the availability of modern camping facilities. Below Alcona Dam, the river is considerably warmer, and provides a lightly exploited fishery for smallmouth bass, walleye, and stocked brown and rainbow trout. Riparian lands between Alcona and Loud ponds are managed by the USFS as a quiet area with motorized vehicle access to the river being prohibited. As a result, this reach provides a wilderness setting that is unique to Lower Peninsula rivers. Loud and Five Channels ponds have limited fishery potential (see **Fishery Management**) and provide poor-fair fisheries for smallmouth bass, northern pike, walleye, and rock bass. Small boat access occurs at both ponds. The entire segment is mostly medium to very high gradient, and where not impounded, provides excellent canoeing. The highest gradient (best) canoeing and kayaking waters are under Alcona and Five Channels ponds. The recreational fishery and canoeing potential of the segment is now limited by dams on the river and a lack of structures for passing Great Lakes fishes to existing riverine reaches.

Five Channels Dam to Foote Dam

Cooke and Foote ponds provide fair to good fisheries for cool- and warm- water fishes such as smallmouth bass, largemouth bass, walleye, northern pike, rock bass, yellow perch, and sunfishes. These fisheries are popular due to modern campground facilities along the river. The recreational fishery and canoeing potential of the segment is now limited by dams on the river. Without dams this segment could provide a fisheries for many valuable Great Lakes fishes (see **Fishery Management**).

Foote Dam to Lake Huron

The river here is very large (170-250 ft wide) and has moderate to low gradient. There are good angling opportunities for potamodromous and river-resident fishes such as steelhead, chinook salmon, brown trout, smallmouth bass, walleye, and channel catfish. Surveys of the fishery for the 1986-1988 fishing seasons revealed an average of 142,924 angler hours and 32,310 angler days being spent in this reach each year (Rakoczy and Rogers 1987; Rakoczy and Rogers 1988; Rakoczy and Rogers 1990). Using an average of $54 per angler day (United States Department of the Interior, Fish and Wildlife Service, and United States Department of Commerce, Bureau of the Census 1991), the value of the fishery has averaged $1,744,763 per year.

Insight Marketing, Inc. (1993) conducted a recreation use survey in association with re-licensing of the Consumers Energy hydroelectric projects. For the fall of 1992 through the summer of 1993 they estimated recreational user days for the river from Mio Pond to Lake Huron based on counts at 10 sites along the river. Estimated numbers of user days per year for different use categories are as follows: reservoir fishing- 605,000 user days; tailrace fishing- 570,000 user days; canoeing- 363,000 user days; boating and water skiing 448,000 user days; camping- 528,000 user days. These numbers need to be interpreted cautiously because estimates of recreational use per year appeared to be extrapolated from counts made at sites only during seasons of peak usage. Also the number of days sampled per season was low. Number of days sampled for each season was: fall- 10; winter- 10; spring- 6; and summer- 12. Such problems may explain, for example why the tailrace fishing estimate (570,000 user days) is nearly 20 times higher than the 3-year average angler use estimate for the river downstream of Foote Dam (32,310 angler days) determined from much more intensive Fisheries Division surveys (Rakoczy and Rogers 1987; Rakoczy and Rogers 1988; Rakoczy and Rogers 1990). If the 1992-1993 data are comparable across categories, the data show that angler use of the relatively short tailrace reaches (570,000 user days) is nearly as great as that in the much longer reservoir reaches (605,000). Similarly, canoeing use (typically a riverine form of recreation) is nearly as high as boating and water skiing use of the ponds (363,000 user days versus 448,000 user days). More intensive surveys are needed to better quantify recreational use of the lower mainstem.

Major Tributaries

The headwaters of the East, South, and North branches of Au Sable River, Big Creek-North, Big Creek-South are small size streams less than 25 ft in width. All provide few angling opportunities in their upper reaches, but trout fishing further downstream as groundwater inflows promote coldwater fishes (Figure 8). Log jams and the narrowness of the channel limit canoeing.

East Branch Au Sable River

It provides excellent angling for brook and brown trout. Its headwaters are contained within the Camp Grayling Army National Guard facility and are closed to the public. The East Branch Au Sable River has mostly sand and gravel substrates. It is narrower and has more woody debris in its channel relative to the other branches of the Au Sable River (Table 4). These characteristics make for difficult to impossible canoeing. The county-owned, Grayling Fish Hatchery is located near the river mouth in Grayling. The East Branch Au Sable River between the hatchery and the river mouth has been unofficially designated as an area for kids to fish.

North Branch Au Sable River

This stream provides excellent angling opportunities for wild brook and brown trout. The river is about 70-120 ft wide, with a mixture of sand and gravel substrates, and easily wadable. Of the three reaches in the Au Sable River where data are available (Table 27), the North Branch Au Sable River had the lowest values for angling pressure (1790 hrs/mi), brown trout catch (210 fish/mi), and total trout catch (460 fish/mi). It had the highest brook trout catch (250 fish/mi). Angling pressure and trout catches declined in the late 1980s, and are thought to be at low levels relative to previous years. No estimates on canoeing traffic are available and the river is generally not canoed due to its shallowness during the summer.

Big Creek-North consists of three tributaries that enter the North Branch near its mouth. All are small (<30 ft wide), and have sand and gravel substrates. The West Branch Big Creek-North provides excellent angling for brook and brown trout, while the Middle and East branches provide marginal-poor angling for these species due to temperature elevation from lakes and beaver ponds. There is no canoeing on Big Creek-North due to its logjams and logs across the channel. Big Creek Impoundment on the Middle Branch Big Creek-North provides fair angling for walleye, northern pike, smallmouth bass, largemouth bass, and bluegill.

South Branch Au Sable River

This stream provides excellent angling opportunities for wild brown trout and brook trout. The river is 50-70 ft wide and wadable, with a mixture sand, gravel, and clay substrate. This tributary receives an intermediate amount of angling pressure relative to the mainstem and North Branch Au Sable River (Table 27). For 1981-1990 angling pressure from Chase Bridge to Smith Bridge was estimated as 2280 hrs/mi. Catch per mile of brook and brown trout were between those of the mainstem and North Branch Au Sable River (Table 27). Angling pressure and catch levels increased during the late 1980s, and are thought to have remained fairly stable during the 1990s. Canoe use is moderate and did not show any clear up or down trend during the 1980s (Table 27). This stretch is which is almost entirely contained within the Mason Tract. George Mason gave the Mason Tract to the State of Michigan under condition that it be preserved in its wild state for the benefit of anglers and hunters. It is cherished by many due to its wilderness character. Vehicle access from which anglers may walk to the river occurs in limited areas of the Mason Tract.

Big Creek- South

Big Creek- South provides excellent angling for brook and brown trout. It is less than 30 ft wide, and has sand and gravel substrate. Wading can be difficult due to woody debris in the stream channel. There is no canoeing due to its small size and the presence of logjams.

Pine River

The Pine River system provides good angling for resident brook and brown trout, and limited opportunities for chinook salmon and steelhead. There is considerable potential to improve potamodromous angling opportunities in the river by improving fish passage over the Van Etten Lake-level control structure. Tributaries of the Pine River are generally small in size, (less than 25 ft in width) with sand, gravel, and clay substrates, and are generally wadable, except for reaches containing large amounts of woody debris and beaver floodings. Streams in the Pine River system are generally too small for canoeing.

Citizen Involvement

Citizen involvement in management of the Au Sable River occurs through interaction with government agencies that manage water flows, water quality, animal populations, land use, and recreation. Government agencies include: MDNR; Michigan Department of Military Affairs; USFS; United States Fish and Wildlife Service; United States Department of Agriculture (USDA) – Natural Resource Conservation Service; Huron Pines Resource Conservation and Development Council; various county road commissions; and township and county offices.

Non-governmental organizations that are in contact with MDNR Fisheries Division have an interest in and actively work on various aspects of the Au Sable River watershed include: Anglers of the Au Sable; Au Sable Manistee Action Committee; Au Sable River Property Owners Association; Au Sable River Protection Association; Federation of Fly Fishers; Michigan Council of Trout Unlimited; Michigan Fly Fishing Club; Michigan Hydropower Relicensing Coalition; Michigan

Salmon and Steelheaders Association; Michigan United Conservation Clubs; North Branch Area Property Owners Association; Northeast Michigan Sportsman's Club; Recreational Canoe Association; and Walleyes for Iosco County.

As the future brings changes, it is important that the value of the Au Sable River to the region is kept, or enhanced. Many interest groups have diverse ideas regarding the future of the watershed and how the river system should be managed. Sometimes their views are limited to specific issues or geographic portions of the system, and may conflict with views of other groups. A basin-scale forum (or watershed council) would provide a means for groups to work together to identify the most important issues in the watershed and develop a shared vision and set common goals for the future of the Au Sable River. A watershed council could provide the forum for exchange of information, experiences, and ideas between communities, interest groups, governmental entities, and interested citizens. Examples of watershed councils filling these roles now exist in other areas of Michigan.

MANAGEMENT OPTIONS

In its present state, the Au Sable River is a high quality resource that has tremendous additional fishery and recreation potential. A number of fishery-related problems need attention before this potential can be realized. The management options presented in this plan address the most important, presently understood problems and establish priorities for further investigation.

The options follow the recommendations of Dewberry (1992), who outlined measures needed to protect the health of the nation's riverine ecosystems. Dewberry stressed protection and rehabilitation of headwater streams, riparian areas, and floodplains. Stream segments need to be re-connected to each other, and the channel needs to be reconnected its floodplain. We must view the river system as a whole, because system-level processes are the primary influence on stream habitat and fish communities through time.

The identified options are consistent with the mission statement of the MDNR Fisheries Division. Its mission is to protect and enhance the public trust in populations and habitat of fishes and other forms of aquatic life, and promote optimum use of these resources for the benefit of the people of Michigan. In particular, Fisheries Division seeks to: protect and maintain healthy aquatic environments and fish communities; rehabilitate those communities now degraded; provide diverse public fishing opportunities to maximize the value to anglers; and foster and contribute to public and scientific understanding of fish, fishing, and fishery management.

Options convey three approaches to addressing problems in the watershed. First, we present options to protect and preserve existing resources. Second are options requiring additional surveys to help direct management. Third are opportunities for rehabilitation or restoration of degraded resources. Opportunities to improve an area or its resources, given its present status, are listed last.

Geology and Hydrology

The Au Sable River has extremely stable flows. Several reaches, however, have less stable flows than expected or desired. Increasing urban development in areas has the potential to reduce the stability of river flows. The most severe flow problems are caused by operation of the complex of dams from Mio to Oscoda and lake-level control structures.

Option: Protect the natural hydrologic regime of streams by protecting existing wetlands, flood plains, and upland areas that provide recharge to the water table.

Option: Protect and restore groundwater recharge by requiring that all development-related runoff be captured by infiltration basins.

Option: Protect the natural seasonal flow patterns of the river by incorporating best management practices and requiring that no additional runoff enter the river from land development.

Option: Protect existing hydrologic conditions of lakes and remaining natural lake outlets by prohibiting construction of new lake-level control structures. This would assure occurrence of natural water level fluctuations needed to maintain wetlands in the lake and at lake outlets.

Option: Restore natural hydrologic regime of streams by removing dams when possible, and requiring existing dams to strictly adhere to run-of-river flow operation.

Option: Restore natural hydrologic regime of lakes and lake outlets by removing lake-level control structures when possible.

Option: Restore headwater, tributary, and mainstem run-of-river flows by operating lake-level control structures as fixed-crest structures with wide spillways rather than by opening and closing gates.

Soils and Land Use Patterns

Soils in the Au Sable River watershed are generally coarse-textured, providing high infiltration and groundwater recharge, but are also extremely erodible and susceptible to improper land use. Many fire-maintained prairies and pine forests have been replaced by deciduous forests due to fire suppression. Residential development within the watershed is proceeding relatively rapidly, pointing to the need for greater land use planning.

Option: Protect watershed soils from improper land use by encouraging formation of a basin-wide, locally-based watershed council to assist in land use planning, development, and other river protection issues.

Option: Protect undeveloped private riparian lands by bringing lands under public ownership or through economic incentives such as tax credits, deed restrictions, conservation easements, or other means.

Option: Protect lands through land-use planning and zoning guidelines that emphasize protection of critical areas and discourage alteration of natural drainage patterns. Support development of zoning standards for townships presently not zoned.

Option: Protect channel from excessive sediment delivery by supporting inventories of erosion sites within the watershed, and remediation activities directed at those sites.

Option: Protect the river from excessive sedimentation by encouraging education of workers involved in road siting, construction, and maintenance regarding use of best management practices (BMPs).

Option: Protect the river from excessive sedimentation by reducing densities of oil and gas well pads. This can be accomplished by increasing spacing between oil and gas well pads and supporting increased use of angular drilling techniques.

Option: Protect the river from excessive sedimentation associated with oil and gas development by requiring quicker re-vegetation of soils in effected areas.

Option: Protect channel from excessive sediment delivery by using BMPs at road-stream crossings. Support cooperative funding in situations when local road commission budgets are inadequate for use of BMPs.

Option: Protect the river within the Au Sable State Forest by developing a forest management plan that addresses water quality issues.

Option: Protect channel from excessive sediment delivery from State Forest roads by supporting efforts to appropriate funds for their maintenance.

Option: Survey road-stream crossings to identify problem areas and implement BMPs.

Option: Restore lost fire-maintained prairie and savannah habitats where possible, and discourage development in fire-prone upland habitats, such as outwash plains.

Channel Morphology

Compared to other rivers in Lower Michigan, the Au Sable River is a high-gradient stream. Dams now impound many of the highest gradient reaches on the mainstem, particularly in the middle and lower portions of the river. Past logging activities eliminated old-growth riparian forests, and altered stream channel shape by removing large woody debris and increasing sedimentation. Removal of the river's excess sediment bedload may require decades due to the river's stable flow characteristics. Relatively young, second growth forests provide less shading and contribute a limited amount of woody debris to the stream channel. Residential development along the riparian corridor has eliminated some riparian forest and natural stream bank habitat.

Option: Protect diverse stream channel habitats by preventing removal of large woody debris now in the river.

Option: Protect and restore riparian forests by educating riparian residents on how riparian forests influence water quality, stream temperatures, trophic conditions, channel morphology, bank erosion and stability, and aquatic, terrestrial, and avian communities.

Option: Protect riparian greenbelts through adoption and enforcement of zoning standards.

Option: Protect riparian corridors of Consumers Energy ponds by maintaining current ownership or transferring ownership to state and federal agencies. This will prevent fragmentation and residential development of riparian habitat.

Option: Survey channel characteristics of the upper mainstem and compare them to past records to assess the rate and extent of channel changes. Data are especially needed in the Headwaters to Wakeley Bridge and Wakeley Bridge to Mio Pond segments.

Option: Survey cold water streams to identify where high beaver activity (or beaver dam density) adversely affects riparian habitats and stream channel morphology.

Option: Restore high-gradient habitat in the upper mainstem by removing Grayling Dam.

Option: Restore extremely rare, high-gradient reaches of the lower mainstem by removing dams, with top priority on Five Channels and Alcona dams which impound >10 ft/mi gradient habitats.

Option: Restore rare high-gradient habitats by removing dams no longer used for their original purpose (for example, retired hydroelectric facilities), dams which are a safety hazard, and dams serving little purpose.

Option: Rehabilitate channel diversity by removing excess streambed sediment load and controlling sediment contributions.

Option: Improve channel diversity by adding woody debris or habitat improvement structures in reaches where channel diversity is low, or in reaches where natural contributions of large woody debris have been reduced. Examples are in areas where residential development or past logging practices have eliminated old-growth riparian forests or instream logjams (e.g. mainstem upstream of Mio Pond, and North and South branches of the Au Sable River), and in reaches below dams (e.g. Consumers Energy dams) which block downstream transport of woody debris.

Dams and Barriers

One hundred and nine (109) dams are within the watershed. These dams impound considerable high-gradient habitat, block potamodromous migrations of fishes, block migrations of resident fishes, eliminate wetlands at lake outlets, create flow fluctuations in streams and eliminate natural lake-level fluctuations, trap sediments and woody debris, elevate stream temperatures, and impair water quality.

Option: Protect biological communities of the river by providing upstream and downstream fish passage at all dams to mitigate for habitat fragmentation.

Option: Protect fishery resources by screening turbine intakes at operating hydroelectric dams.

Option: Protect the Au Sable River from invasion by sea lamprey by modifying fish passage structures at Foote Dam and the Van Etten Lake-level control structure.

Option: Protect the public trust by requiring dam owners to make appropriate financial provisions for future dam removal or perpetual maintenance.

Option: Survey and develop a list of barriers to fish passage, and correct those that are fragmenting the system.

Option: Survey dams on tributaries to identify areas where environmental damage and the need for mitigation are greatest.

Option: Survey State-owned dams to determine their usefulness or potential for removal.

Option: Restore valuable cold water, riverine habitat by removing Grayling Dam and Robinson Creek Flooding Dam.

Option: Restore free-flowing river conditions by removing dams no longer used for their original purpose (e.g. retired hydroelectric facilities, dams which are a safety hazard, and dams serving little purpose).

Option: Restore natural river flows at hydropower dams, lake-level control structures, and other dams by requiring dam owners to operate at run-of-river.

Option: Restore natural transport of sediment and woody debris by removing all dams on the mainstem Au Sable River.

Option: Restore natural fluctuations in lake levels by removing lake-level control structures when possible.

Option: Rehabilitate the former productivity of the Au Sable River for Lake Huron fishes by removing dams on the lower mainstem and installing fish passage structures at remaining dams.

Option: Rehabilitate cold water temperature conditions downstream of Mio and Alcona dams by removing them or modifying dams to enable cold water releases.

Option: Rehabilitate run-of-river flows at lake outlets with existing lake-level control structures by physically modifying dams so that such flows are maintained. For example, fixed crest dams with wide spillways could be installed at lakes that can potentially release large volumes of water.

Option: Rehabilitate natural river flows by amending the Lake-level Control Act.

Water Quality

Water quality is excellent throughout much of the watershed. However, dams significantly impair water quality on the mainstem. Effects of dams on the water quality of tributaries are unknown. Many contaminated (Act 307) sites exist in the watershed and need to be cleaned up.

Option: Protect water quality downstream of Consumers Energy dams by continuously monitoring water temperatures and dissolved oxygen levels, and seeking mitigation for violations of water quality standards.

Option: Protect water quality by protecting existing wetlands, rehabilitating former wetlands, and maximizing the use of wetlands and floodplains as natural filters.

Option: Protect the river by implementing best management practices for storm water and nonpoint source pollution.

Option: Survey water quality characteristics (especially nutrient levels) at sites in the watershed where historic data exist to better determine the extent of temporal changes in water quality.

Option: Survey effects of non-point source pollutants (especially salt brines) on river water quality characteristics.

Option: Survey temperature elevation effects of other dams in the watershed, and develop a list of dams having the greatest thermal effect on downstream reaches.

Option: Survey dissolved oxygen levels below other dams in the watershed to determine where effects are greatest.

Option: Survey loading of nutrients and sediments to the river and develop strategies to reduce identified problems.

Option: Rehabilitate cold water temperatures below dams by removing or physically modifying dams to reduce their thermal effects on downstream reaches. For example, Grayling Dam could be removed, and Mio and Alcona dams could be physically modified to release cold water.

Option: Restore water quality in the Pine River system by preventing livestock from accessing streams.

Option: Restore water quality by supporting Act 307 site cleanups.

Special Jurisdictions

The Federal Energy Regulator Commission licenses six active hydropower facilities in the watershed. The State of Michigan and United States Government own large amounts of land in the watershed, including important riparian habitats. They are also responsible for administering laws necessary for protection of the environment and biological communities. Local units of government and county road commissions are responsible for road-stream crossings and many lake-level control structures which affect sedimentation rates and streamflow conditions in many areas.

Option: Protect and restore the river system by supporting cooperative planning and decision-making. Develop a Geographic Information System that could be used to facilitate these processes.

Option: Protect and restore the lower mainstem by holding all parties to terms of the Settlement Agreement reached for the six Consumers Energy dams.

Option: Protect the river corridor from development by giving the State Natural Rivers Act and the Au Sable River Natural Rivers Plan the force of law.

Option: Survey existing statutory authorities to determine if additional statutory authority is needed to protect the river system.

Option: Survey, review, and coordinate all land management plans for state, federal, and corporate lands to ensure adequate protection of the river system.

Biological Communities

Biological communities are generally healthy, though they are considerably different than what was originally present. Some native species have been greatly reduced or lost (e.g. Arctic grayling and upriver populations of lake sturgeon) while other species have been introduced, some desirable (e.g. salmonids) and others undesirable (e.g. carp and sea lamprey). Many attempts to restore Arctic grayling have failed, in part because of the species' apparent need for large, cold, un-fragmented rivers with few competing species (Nuhfer 1992). Most significant change to biological communities results from fragmentation of the system, loss of high-gradient habitats, and alteration of water quality by dams. Present stream habitats show reduced levels of fish abundance and production, due to the lack of a large potamodromous fish component, that being inland migrations and production of Lake Huron fishes. Present aquatic communities in areas throughout the system, and especially in the lower mainstem, contain proportionately more cool- and warmwater species than coldwater fishes due elevation of summer temperatures by impoundments. Accelerated soil erosion and stream sedimentation in certain areas has reduced the availability of clean gravel-cobble habitats important to many aquatic species. Rarity of other species that require old growth forest (particularly floodplain forests) and large, free-flowing rivers shows the need to protect and restore these habitats in the watershed.

Option: Protect gravel habitats from sedimentation due to land development by enforcing local soil and sedimentation codes. Implement nonpoint source best management practices at construction sites.

Option: Protect stream margin habitats, including floodplains and wetlands, by requiring strict enforcement of Natural Rivers and local zoning regulations and controlling development in the stream corridor.

Option: Protect biological communities associated with remaining high-gradient riverine habitats.

Option: Protect resident, naturally-reproducing fish populations by screening all private and public fish stockings to ensure they are free of diseases and undesirable species.

Option: Survey the historic record to determine pre-settlement flora, fauna, and habitat conditions in the watershed.

Option: Survey the present distribution and status of fishes, aquatic invertebrates, mussels, amphibians, reptiles, aquatic plants, and pest species throughout the river system.

Option: Survey the lower mainstem to assess the status of fishes of special concern and to aid in development of recommendations for protection and recovery of their populations.

Option: Survey fish riverine communities in mainstem from Wakeley Bridge downstream to the river mouth using intensive methods.

Option: Survey stream temperature conditions in riverine portions of the lower mainstem to better assess the potential of these waters for different fishes.

Option: Restore potential for fishes to migrate throughout the river system by removing dams whenever possible.

Option: Restore historic runs of potamodromous fishes and the productive capacity of remaining high-gradient, riverine reaches in the lower mainstem by removing barriers or installing fish passage structures to re-connect them to Lake Huron

Option: Restore lake sturgeon populations in the lower mainstem by stocking fish into lower river impoundments.

Option: Rehabilitate gravel habitats by removing excessive sand bedload from the upper mainstem and its tributaries.

Fishery Management

Stable, groundwater-dominated flows represent the key value of the Au Sable River. The river has the potential to support substantial populations of highly-valued, coldwater fishes along much of its length. Fishing is good in most parts of the watershed. Much of the upper mainstem and its tributaries provide excellent fishing for self-sustaining populations of brown and brook trout. In other areas, salmonid populations are adversely affected by a lack of woody structure, habitat fragmentation, elevated water temperatures, unnatural flow fluctuations, excessive sedimentation, and sand bedload.

Six large ponds on the lower mainstem have altered the river, limiting the potential for its management as a cold water river. Groundwater-dominated flows and high flushing rates through the ponds limit their ability to support valuable fisheries for cool- and warm-water lake fishes. Thus the lower mainstem provides only fair to good fishing. These ponds, and a lack of fish passage to remaining upstream riverine reaches, limit development of valuable riverine fisheries for trout and potamodromous fishes.

Option: Protect fish communities in Lake Huron from sea lamprey by placing a lamprey barrier on the mainstem downstream of the mouth of the Pine River.

Option: Protect self-sustaining trout stocks by discouraging stocking on top of these populations. If fish are stocked, require the stocked fish be certified as disease-free.

Option: Protect self-sustaining trout stocks by developing an educational pamphlet that addresses Fisheries Division concerns related to fish stocking.

Option: Protect habitats for large fishes throughout the river system by protecting existing riparian forests.

Option: Protect fish communities and improve ability to target fisheries management by initiating ecosystem-level monitoring of physical and biological characteristics of the mainstem and tributaries throughout the watershed.

Option: Survey potential for re-introducing lake sturgeon in remaining riverine reaches (i.e. above Mio Dam, Mio Dam to Alcona Dam, and Alcona Dam to Loud Dam)

Option: Survey submerged structural habitat in Loud and Five Channels ponds.

Option: Survey beaver populations and effects on cold water tributaries. Identify measures to control beaver populations where effects are excessive.

Option: Survey stream temperature conditions in riverine habitats between Wakeley Bridge and the river mouth to assess potential for different sport fishes and help target management to most appropriate species.

Option: Survey sport fisheries from Wakeley Bridge to the river mouth to assess fishing pressure, catch, and economic value.

Option: Survey biological communities and fisheries of comparable streams with and without potamodromous runs to evaluate biological and fishery effects of fish passage.

Option: Survey options for discharging cold water from Mio and Alcona ponds to improve downstream habitat for salmonid reproduction and survival.

Option: Manage the river upstream of Mio Pond to provide a high quality fishery for resident, naturally-reproducing brook trout and brown trout stocks.

Option: Manage the river downstream of Mio Pond to provide high quality fisheries for stocked and naturally reproduced salmonids.

Option: Manage fish communities in the mainstem ponds recognizing the limited potential of these habitats.

Option: Restore cold water riverine fisheries and habitats by removing dams.

Option: Restore runs of native and naturalized fishes, other than sea lamprey, by providing upstream and downstream fish passage at dams.

Option: Restore fish communities in river delta habitats by removing dams and allowing natural downstream transport of sediment to Lake Huron.

Option: Restore high-gradient habitat for lake sturgeon by removing dams on the lower mainstem (especially Alcona, Loud, and Five Channels dams) and providing passage into riverine reaches.

Option: Restore connections between habitats by removing dams no longer used for their original purpose, dams which are a safety hazard, and dams serving little purpose. For example, Grayling Dam.

Option: Rehabilitate fish communities and habitat by removing state-owned dams on trout streams.

Option: Rehabilitate stream habitats and wetland habitats at lake outlets by working with owners of private dams on lake-level management issues.

Option: Improve habitats for large salmonids in the mainstem (Headwaters to Wakeley Bridge) and North Branch Au Sable River by adding large woody debris.

Option: Improve survival of fishes migrating downstream by providing fish passage and screening turbine intakes at hydropower facilities.

Recreational Use

The watershed provides extensive recreational opportunities. Angling use and canoe traffic are heavy on presently available riverine reaches. The number of commercial canoes registered for use on the river has exceeded the limit identified in the Au Sable River Natural Rivers Plan (Anonymous 1987). Impoundments on high-gradient reaches of the lower mainstem from Mio Pond to Foote Dam have the potential to provide spectacular riverine fisheries, and some of the best canoeing, kayaking, and sightseeing waters in Lower Michigan. Present fishery and recreational opportunities in this reach range from fair to good. Public access to the river is generally good.

Option: Protect the river by supporting efforts to minimize conflicts among user groups and requiring compliance with guidelines in the Au Sable River Natural Rivers Plan.

Option: Protect the river by giving the State Natural Rivers Act and the Au Sable River Natural Rivers Plan the force of law. This would strictly limit commercial watercraft use on the river to 1987 levels as identified in Au Sable River Natural Rivers Plan.

Option: Protect the river by having all commercial watercraft (e.g. canoes, kayaks, and boats) included in the count toward the maximum number of commercial watercraft permitted for use on the river. Commercial use of inflatables and inner tubes on the river should be banned.

Option: Survey level of recreational use of the lower mainstem and its ponds by anglers, canoeists, and boaters. Estimate the economic value of the lower mainstem in its present state for comparison with economic estimates made for different river management scenarios, such as the lower mainstem without dams.

Option: Improve recreational fishing potential of the lower mainstem by removing dams when possible and providing upstream passage of Lake Huron fishes into existing riverine reaches.

Option: Improve existing small-scale public access sites to minimize their effects on the river.

Option: Improve public access at hydropower facilities under FERC re-licensing agreements.

Citizen Involvement

Citizen involvement is a critical component to the management of the Au Sable River watershed. Continuous interaction between management entities, user groups, and interested citizens is needed to support fisheries management activities.

Option: Protect and restore watershed integrity by building public support through a network of citizen involvement groups.

Option: Protect the Au Sable River system by encouraging formation of a locally-driven, basin-wide watershed council to direct watershed planning and management of the river system from a long-term, broad-based, community-oriented perspective.

Option: Protect and rehabilitate the watershed by educating river users and property owners on sound watershed management.

Option: Protect the river by supporting efforts of interest groups seeking funding to protect and improve the river system.

Option: Protect the river by developing an Au Sable River web site for exchange of information on the river.

Option: Protect the river by conducting an economic study to determine the river's value to local communities. Use findings to educate others of the value of the Au Sable River to the region.

Option: Protect the basin by continuing to work cooperatively with governmental and non-governmental groups on common stewardship issues.

Option: Survey other watersheds in the state to identify watershed councils that could serve as mentors or guides in formation of an Au Sable River Watershed Council.

COMMENT AND RESPONSE

A draft of this assessment was first distributed for public review in summer 1995. After receiving comments, the assessment was re-written and again sent out for public review on December 17, 1999. Statewide MDNR Press Releases were issued in conjunction with release of both drafts of this report. During both reviews copies were sent to local and selected state-wide offices: MDNR (Forest Management Division, Wildlife Division, Parks and Recreation Division); MDEQ (Surface Water Quality Division, Land and Water Management); Michigan Department of Military Affairs; United States Forest Service; United States Fish and Wildlife Service; and Huron Pines Resource Conservation and Development Council. Local units of government and other organizations receiving copies included: Michigan Hydro Relicensing Coalition; Au Sable River Property Owners Association; Consumers Energy; Anglers of the Au Sable; Michigan Recreational Canoe Association; Lake Huron Sportfish Inc.; North Branch Property Owners Association; Northeast Michigan Sportman's Association; Trout Unlimited; Au Sable River Restoration Committee; Oscoda Press; and various township offices. Copies were also sent to the following libraries: Otsego County Library in Gaylord; Crawford County Library in Grayling; Lewiston Public Library in Lewiston; Gerrish-Higgins School District Public Library in Roscommon; Oscoda County Library in Mio; and Robert Day Parks Library in Oscoda. A letter explaining the purpose of the assessment and requesting review comments was enclosed with each copy. All individuals requesting a copy received one. Copies for distribution upon request were available at the Grayling and Ann Arbor Fisheries Division offices.

Public meetings to receive comments concerning the assessment draft were held on June 6, 1995 at the Crawford-Au Sable Schools in Grayling; June 7, 1995 at the Mio-Au Sable Schools in Mio; and on June 8, 1995 at the Oscoda Area High School in Oscoda. Public notices were published before the public meetings in the Crawford County Avalanche, Oscoda County Herald, Bay City Times, and Oscoda Press. Attendance at these meetings was estimated at: Grayling- 20 people; Mio- 40 people; and Oscoda- 15 people. Public comment was incorporated into the 1999 assessment draft.

The initial comment period for the 1999 assessment draft was scheduled to end on January 17, 2000, but was extended to February 17, 2000 to accommodate additional requests. In addition, comments were accepted for over a month beyond February 17. All comments received were considered. Similar comments were combined to avoid unnecessary duplication. Suggested changes were either incorporated into the final document or listed along with the reason they were not included.

Executive Summary

Comment: Numerous comments were received that the Au Sable River Assessment provides an excellent compilation of information describing the Au Sable River system. Substantial information describing past and present physical and biological conditions along the river are clearly presented. The Assessment is "a fine and valuable document reflective of scientific rigor, concerned analysis, and thoughtful projection". The document lists a large number of management options for consideration, and provides a good starting point for management discussions. The Assessment should stand as a good resource document for management of the river for many years.

Response: Thank you.

Comment: "The statements are made here that the Assessment is 'intended to increase public concern for the river' and 'encourage citizens to become more actively involved in decision-making processes.' These statements are, however, contradicted by the lack of any plans to hold public meetings on the contents of the Assessment and the identified Management Options. This hardly seems like an effective approach 'intended to increase public concern' and 'encourage citizens to become more actively involved.' Consumers reiterates here its call for MDNR to adequately advertise and hold public meetings at several locations throughout the Au Sable River watershed."

Response: As stated in the paragraph quoted, "river assessments are intended to provide a comprehensive reference". The assessment itself is not a decision making process, but rather a reference for those interested in the river. The assessment provides the information base for developing fisheries management plans. Public comment is always welcome in the management planning process. Public meetings were held in 1995 and comments received were incorporated into the draft that went out for review in 1999-2000. Meetings were not held in 1999-2000 due to the lack of attendance at the 1995 meetings.

Comment: "The statement is made here that lowland conifer forests along the lower mainstem have been lost due to inundation by impoundments. This statement is misleading in that these lowland conifer forests were originally lost to lumbering as is recognized elsewhere in the Assessment."

Response: The wording of the sentence has been clarified. We agree that these forests were cut before creation of the ponds, but they would have regrown had the ponds not flooded the river's original floodplain.

Comment: "There are many subjective statements made here [paragraph 15 in **Executive Summary,** Au Sable River Assessment Draft] about the effects of the hydroelectric projects that are not supported by data in the Assessment itself. In fact, the Assessment indicates elsewhere that more data is needed to accurately assess the condition of the various resources mentioned here and the impacts of the hydros on those resources."

Response: We disagree. All statements made in this paragraph are supported by data in the document.

Comment: "This paragraph [paragraph 15 in **Executive Summary** Au Sable River Assessment Draft] then references the fish entrainment and mortality estimates developed in 1990/1991 as part of the relicensing of Consumers' six Au Sable River hydros. It should be noted that these fish entrainment estimates are based on hydroacoustic sampling and partial discharge netting techniques which are no longer generally accepted by the resource agencies (including MDNR) or hydroelectric industry for use in estimating fish entrainment rates. Sampling at the Foote Hydroelectric Project in 1999 using tailrace nets which sampled the entire discharge of the plant (in connection with the 1998/1999 installation of fish protection devices or stoplog screens) has documented much lower fish entrainment rates (by more than an order of magnitude) of largely young-of-the-year fish (for the unscreened or unprotected condition). These results cast even more doubt on the validity of the 1990/1991 fish entrainment and mortality estimates discussed here and elsewhere in the Assessment."

Response: The entrainment data used in this report provided the basis for the Settlement Agreement and was the best information available at the time this document was written and reviewed. The information you are referring to for the Foote Project has not yet been received by

Fisheries Division as either raw data or a final report (K. Kruger, MDNR, Fisheries Division, personal communication). In addition, the 1990 entrainment data is the only and best information available for the other five Consumers Energy projects. We welcome the opportunity to review any future entrainment data for these projects.

Comment: "The statement is then made [paragraph 15 in **Executive Summary** Au Sable River Assessment Draft] that populations of some fish species are reduced such that they need special protection (e.g. lake sturgeon) implying that demise of these species was due to the construction of the hydros when in fact, as the Assessment recognizes elsewhere, the demise of this and other fish species is directly attributable to the lumbering era and over fishing in the late 1800s and early 1900s."

Response: While the demise of some species (e.g. Arctic grayling and some Lake Huron salmonids) may be attributable to a number of factors, the lack of recovery of several fishes (including lake sturgeon, walleye, several Lake Huron salmonids, and other species) is largely attributable to dams which impound suitable riverine habitat and spawning rapids, and prevent spawning fishes from accessing upstream spawning sites (Smith 1972; Hay-Chmielewski and Whelan 1997).

Comment: "Several broad statements are made here [paragraph 16 in **Executive Summary** Au Sable River Assessment Draft] to the effect that dams can adversely affect stream temperature and oxygen levels, that excessive temperature elevation of cold water reaches occurs at the six hydros, and that dissolved oxygen levels fell below required minimums on several occasions at Consumers' six hydros. These broad statements ignore the fact that water temperatures and dissolved oxygen levels downstream of the hydros are also directly influenced by the value of these same parameters present in the Au Sable River upstream of the hydros. In fact, monitoring during the past three years indicates that there are times when water temperature and dissolved oxygen levels upstream of the hydros fail to meet State water quality standards. Finally, the statement is made that continued monitoring is needed to document and seek mitigation for the effects of these dams."

Response: These statements are accurate as written. Evaluation criteria and data on the warming of the river by Consumers Energy projects, which include the comments stated, were presented in the Settlement Agreement (**Appendix 1**) and **Water Quality** portions of this document.

Comment: "The statement is then made concerning the ill effects of Consumers' six hydros on the invertebrate communities when comparing 1970 and 1990 survey data from above and below the hydros. This statement ignores the significant changes in water quality especially related to nutrient levels as a result of improvements in wastewater treatment facilities in the upper watershed. The Assessment itself states, at page 51 [paragraph 2 in **Water Quality**], that 'Reduced biological productivity… may partly explain changes in abundance of the species over time (see **Biological Communities**). Recent water quality data (Table 11) suggest that nutrient levels (e.g. total phosphorus) in much of the river system may be 2-3 times lower than in the past (Tables 9 and 10).'"

Response: The 1970s and 1990s data both consistently show degradation of invertebrate communities in reaches downstream of Consumers Energy hydros. Because these data compare upstream and downstream reaches in the 1970s, and again in 1990s, and the results are consistent through time. The quote cited refers to changes in brown trout abundance in portions of the river downstream of Grayling and Roscommon, and has no relevance to the 1970s and 1990s data indicating degradation to invertebrate communities by Consumers Energy hydros.

Comment: Paragraph 17, "The last two sentences – Advisories due to 'high' PCB levels exist for several fishes in Lake Huron …PCB levels in Lake Huron fishes have declined since the late 1970s and are 'low' relative to levels of fishes in Lake Michigan and Lake Ontario – is confusing".

Response: The wording of these sentences has been clarified.

Comment: "Consumers questions the characterization of 'many' of the watersheds amphibians, reptiles, birds, mammals, and plants as being threatened or endangered. It is also difficult to understand the brevity of discussion given here (one sentence) concerning… the issue of invasion by exotic species…"

Response: The wording was changed to clarify the paragraph. The vast majority of rare species in the watershed are rare because of habitat loss, not exotic species. In fact, Consumers Energy ponds, by warming and slowing down the Au Sable River, increase suitability of river habitats for some exotic species (e.g. zebra mussels, common carp, purple loosestrife, and others). With the exception of sea lamprey, nearly all exotic species now in the Great Lakes do not pose a significant threat to aquatic communities of free-flowing, cold water river habitats.

Comment: "The statement is made here [paragraph 29 in **Executive Summary**] that the lower mainstem has the potential for providing valuable fisheries for resident and potamodromous coldwater fish species if the river were in a free-flowing (unobstructed) state. Such statements are very subjective and ignore the very real cost of either providing fish passage or removing the dams as is implied here. Such statements also ignore the other impacts associated with the very real potential for the introduction of exotic species upstream of the hydros to the detriment of native plant and animal species in the upper watershed. Finally, such statements ignore the management potential of the lower Au Sable River in its present impounded state."

Response: As per the Settlement Agreement (**Appendix 1**), Consumers Energy has agreed to pay for fish passage at any of its projects on the Au Sable River upon agreement of all other parties involved in the Settlement Agreement. Data collected by MDNR, Fisheries Division on potamodromous fisheries on other large rivers (e.g. Manistee and Muskegon) supports our statement that the Au Sable would support valuable fisheries. In addition, the Au Sable River has more high-gradient habitat (now impounded) than either the Manistee or Muskegon rivers; this would add even greater value. Dam removal or fish passage would benefit many native fishes (e.g. lake sturgeon, lake trout, walleye, whitefishes, suckers, etc.) and important naturalized fishes (e.g. rainbow trout (steelhead), brown trout, chinook, and coho salmon). Sea lamprey would have to be blocked from accessing upstream reaches. Populations of other exotics, which are problems in the Great Lakes (such as ruffe, gobies, white perch, and zebra mussels), would do poorly in a free-flowing Au Sable River, because of its cold, unproductive, high-velocity waters (D. Jude, University of Michigan, personal communication). In addition, the change in habitat conditions due to dam removal would substantially reduce populations of exotic species presently residing in the ponds (e.g. zebra mussels, common carp, purple loosestrife, Eurasian milfoil). This document provides considerable discussion of the limited fishery management potential of the existing impoundments.

Comment: Concerning paragraph 30, "The statement 'Available studies on eagle, mink, and river otter suggest that passing contaminated Great Lakes fishes upstream would pose little or no significant harm to their populations.' Is not supported with data that change the conclusions in the risk assessment for mink by Giesy et al. (1994)…. Until current fish concentration data demonstrate that contaminants have dropped nine fold since the 1990 collections, mink will be at risk from migrating Great Lakes fish."

> Response: The level of fledgling success of bald eagles nesting on rivers with heavy runs of Great Lakes fishes supports our position on fish passage. Bald eagles along these reaches are now reproducing at what the U.S. Fish and Wildlife Service characterizes as "healthy" levels (see **Fishery Management**). Those nesting along Great Lakes shorelines are now reproducing at "stable" levels. These data are especially significant because Great Lakes-nesting and potamodromous-nesting bald eagles, by consuming fish and colonial waterbirds, feed at higher trophic levels and are thought to bioaccumulate contaminants more readily than mink or river otter. Such productivity has occurred despite risk assessment studies suggesting bald eagle reproduction in these areas should be severely impaired. Bald eagle productivity data and field observations of mink and river otter in rivers with Great Lakes fish access suggest the findings of risk assessment (laboratory and modeling) studies of mink may be overstated. Still, we support further reductions in contaminant levels in the Great Lakes. We think however, that providing fish passage has the potential to restore lost production of both native Lake Huron fishes, and salmonids presently stocked into Lake Huron (which control alewife populations and provide an important sport fishery). We also think this can be done without causing significant harm to Michigan's bald eagle, mink, or river otter populations.

Comment: "The statement is made here that Consumers' six hydro ponds have limited fishery management potential. In fact, the ponds have the same fishery management potential as any other coolwater or warmwater fishery resource in the State. However, the pond fisheries have suffered from a lack of management by MDNR's Fisheries Division. This lack of past management is evidenced by the repeated statements throughout the Assessment regarding the lack of data concerning these same resources as well as others within the watershed."

> Response: We strongly disagree. As is discussed in many portions of the Assessment (see **Dams and Barriers, Biological Communities,** and **Fishery Management**), the fishery management potential of these ponds is limited (relative to natural lakes), primarily due to their cool summer temperatures and high flushing rates. These factors result in reduced food availability and poorer growth and survival of fishes typical of Michigan lakes. Ponds such as Mio, Alcona, Cooke, and Foote have received intensive fishery management attention by the MDNR with little apparent improvements in fish communities. In fact, these ponds have received more of Fisheries Division's fishery management attention (e.g. fish population surveys, stocking, and fish community modifications) than most natural lakes in the northeast Michigan.

Comment: "The statement is made here that the Au Sable River is a very popular choice among anglers and canoeists, that [angling and canoe] use is typically highest on high-gradient, riverine reaches and concludes that the lower mainstem in a fully free-flowing state would have even greater recreational angling and canoeing potential. The statement is then made that 'Present angling and canoe use on lower mainstem ponds is thought to be light, but needs to be documented to help guide management of the river' (emphasis added). The MDNR appears to ignore the previous recreation use studies conducted as part of the relicensing of Consumers' hydros. These studies (from the Fall of 1992 through the Summer of 1993) documented significant use of the ponds and their shoreline for fishing (about 600,000 user days per year), camping (about 525,000 user days per year), swimming (about 450,000 user days per year), and boating and water-skiing (about 450,000 user days per year) among other activities. (Insight Marketing, Inc. 1993). In addition, Consumers estimated a total of more than 500,000 recreation days in connection with its hydroelectric project's recreation facilities as documented on the 1997 FERC Form 80 for the Au Sable River hydros. This hardly seems to be what might be characterized as 'light' use levels."

Response: Thank you for pointing us to this report–we were unaware of it. Though it was not mentioned in the comment, the report also contained estimates of tailwater fishery and canoe use along this portion of the river. We have incorporated this information into the **Recreational Use** section of the assessment with the addition of the following comments. First, these data need to be interpreted cautiously because of the methods used in making user day estimates (see Insight Marketing, Inc. 1993 and **Recreational Use**). Second, if accurate, these estimates support our statement that the lower mainstem would have greater boating and canoeing potential. These data show that canoeing (occurring mostly in riverine reaches) and tailwater fishing use in the short riverine reaches (about 936,000 user days) is almost as great as boating/water-skiing and reservoir fishing use in the considerably longer impounded reaches (1,053,000 user days).

Introduction

Comment: Why were public meetings not held in conjunction with the release of this draft of the assessment.

Response: Public meetings were not held due to the lack of attendance at public meetings held in 1995, when the initial draft was sent out for public review (see **Comment and Response**). In addition, comments received from those initial public meetings have been incorporated into this draft.

Comment: Distribution of drafts of this report was too limited.

Response: Copies of this assessment draft were sent to 38 individuals representing government agencies and interest groups, 6 libraries in the watershed, and all citizens requesting a copy (see **Comment and Response**). If you know of any individuals to be included on a future review list, please let us know.

Comment: "The statement is made here that the MDNR has written the Assessment from an ecosystem perspective and goes on to state that 'this assessment is admittedly biased towards aquatic systems.' Consumers would simply like to point out the fact that not only is the Assessment biased toward aquatic systems in general, but that it is biased toward coldwater aquatic systems in particular."

Response: This statement was intended to imply that the focus of river assessments lies where Fisheries Divisions expertise is (aquatic systems) and does not imply any value judgment of aquatic versus terrestrial systems, or warmwater versus coldwater fisheries. We modified this statement to better reflect the intent of assessments of Michigan rivers.

Comment: "The statement is made here that a fisheries management plan will be written after completion of this Assessment. Consumers continues to question how all of this, i.e., the present

Au Sable River Assessment and future fisheries management plan, relates to the comprehensive river management plan that was to be developed by MDNR under the terms of the Settlement (see section 9.1.A of Appendix 1 of the Assessment)."

Response: The "comprehensive management plan" is the culmination of the completed Au Sable River Assessment and the resulting fisheries management plan. These documents meet the Federal Energy Regulatory Commission's requirement of a comprehensive management plan and MDNR, Fisheries Division's needs for management of the river. For clarification, the requirement of a comprehensive river management plan only pertains to fish passage issues on the Au Sable River. In addition to completion of these documents, other issues need to be addressed before implementation of fish passage options at any project (see section 9 of Appendix 1 of the Assessment).

History

Comment: "In spite of the preceding discussion relative to the impacts associated with 'Michigan's infamous logging era' and the over harvest of Arctic grayling with daily catches of 'more than one hundred pounds', MDNR attributes the considerable alteration of 'the lower river and its fish community' to the construction of the Consumers' six hydros between 1911 and 1923. From the preceding discussion one has to wonder if there was even a fish community left to be altered by construction of the hydros."

Response: After the logging period, the river still kept much of its core habitat features, primarily cold summer river temperatures, stable streamflows, high-gradient rapids in areas, and connections throughout the entire river system and with Lake Huron. The river and its fish community were poised for recovery until hydropower construction. Construction of the six hydros destabilized flow conditions and excessively warmed 102 of the river's 155 miles. The hydros inundated the highest gradient rapids on the lower 102 miles of the river and eliminated connections within this portion of the river system. The most downstream hydro (Foote) has prevented Lake Huron fishes from accessing riverine habitats in 145 of the mainstem's 155 miles. These changes continue to prevent recovery of aquatic communities in the river.

Comment: "Consumers recommends that the list of issues of concern among stakeholders be expanded to include MDNR's apparent goals of fish passage and/or dam removal and invasion of the Au Sable River by non-native species."

Response: The wording of this statement was changed for clarification. These items are discussed in greater detail in other portions of the document (e.g. **Fishery Management**).

Geology and Hydrology

Comment: "The tributary gage on the South Branch is mentioned (following the mainstem gages), but there is no mention of the East Branch Au Sable River at Grayling."

Response: Data for this gauge was used in several figures, but the location was corrected to read "at Grayling" from "at Hartwick Pines State Park".

Comment: "*Daily Flow*: …Consumers also notes that the flow fluctuation shown on June 25, 1998 in Figure 6 of the Assessment was reviewed and agreed to by MDNR Fisheries Division personnel prior to the change in flow. This change in flow was made in support of tailrace soundings taken downstream of Mio Dam as required under Part 12 of FERC's dam safety regulations."

Response: Your statement is correct. Flow fluctuations such as these are one example of what must occur to maintain safe hydropower facilities on the river. Safety inspections, malfunctions, equipment limitations, and operator error can all cause flows downstream of hydropower facilities to deviate from run-of-river conditions.

Comment: How often have flow fluctuations such as those shown in Figure 9 occurred based on the USGS flow data and are they within the natural range of variation?

Response: Major flow deviations typically occur about once per month and minor deviations occur about once every two weeks. Flow deviations occur due to lightning strikes, mechanical difficulties, and routine repairs and maintenance. These deviations are clearly outside the range of daily variation that occurs in free-flowing reaches of the river.

Comment: Figure 9, "These data are no longer provisional as noted. The provisional reference in the figure caption should be removed. ….It appears that the data were modified by the USGS during review of the records. A copy of the final (corrected) plot is enclosed for your use. Also, the station number for the Mio data needs to be changed to 04136500."

Response: These changes were made and the "final (corrected) plot" data has been incorporated into Figure 9.

Comment: The hydropower dams on the Au Sable River "control the flooding of Oscoda and Au Sable town sites…. But without the dams won't the river flood more often, especially with all the global warming our government keeps telling us about?".

Response: These dams have always been operated as hydropower facilities and have never been used for flood control purposes. Hydro facilities with riverine tailwaters (Mio, Alcona, and Foote) are operated at "run-of-river" meaning that water enters and leaves the hydro facility at approximately the same rate; there is no storage of floodwaters. Due to the sandy geology of the river's watershed, the river would not flood any more frequently without the dams (see **Geology and Hydrology**).

Comment: "…suggest a wording change for 'large pulses of groundwater' to anything but pulses…"

Response: This was changed for clarity.

Soils and Land Use Patterns

Comment: "Sediment delivery reductions – statement is made that there has been an estimated 85% reduction from stabilizing 150 sites on the mainstem. This may be an over-estimate given research on the Pine River (Manistee River Watershed), a typical northern Michigan river in glacial outwash and moraines, that documented 50% of sand bedload being directly attributable to eroding stream banks.

It was also estimated through this research that sand bedload levels could be reduced approximately 40% by stabilizing the severe and moderately eroding stream banks."

Response: We acknowledge that this may be an over-estimate. This estimate is more of an educated guess than a truly quantitative estimate, but it was the best (or only) existing estimate available for the Au Sable River.

Comment: "…percent of the watershed in National Forest lands is approximately 32% instead of 5%."

Response: This change has been made.

Comment: Paragraph 6, *Land Use:* This paragraph should indicate that State Natural Rivers zoning rules apply to the areas discussed.

Response: This has been incorporated into the text.

Comment: There was no discussion on damage done by Antrim gas development with reference to the material written by the DNR biologists, Alexander and Nuhfer.

Response: We agree that sedimentation released to rivers resulting from Antrim gas development clearly has the potential to damage rivers. This is discussed under *Oil and Gas Development* in **Soils and Land Use**. The material written by Alexander and Nuhfer represent estimates of potential damage to streams. Their work led to modifications to Antrim gas development activities and reduced sediment delivery to streams. However, no field studies have quantified the extent of "damage done" by Antrim gas development. Additional restrictions, such as greater spacing of wells and quicker re-vegetation of affected areas, would further reduce sedimentation. These were added in the **Management Options** section.

Channel Morphology

Comment: "Table 3 lists the amount of high gradient water impounded by the hydro projects (not Table 1 as referenced in text). …it would be helpful to see how much higher gradient water currently exists such as a table depicting historic vs. existing higher gradient water."

Response: The table reference has been changed. The information on historic vs. existing higher gradient water is shown in Figure 12 for the entire river and Figure 13 for lower reaches of the river.

Comment: "It is interesting to note from a comparison of the 'channel hydraulic diversity' values reported in Table 4 for the 'uninfluenced' reaches of the Au Sable River upstream of Mio Dam and in the tributaries and those reported in Table 5 for the 'influenced' reaches of the Au Sable River downstream of the hydros that the influenced reaches appear to have a higher amount of 'good' and 'excellent' diversity."

Response: The observation is correct, and is not surprising given how channel hydraulic diversity values are computed. As mentioned in the text, the channel hydraulic diversity values are somewhat biased in that the potential for high diversity increases with stream size. Consequently, upstream-downstream comparisons of channel hydraulic diversity values are probably of little value.

Dams and Barriers

Comment: "*Early Records of Effects of Dams on Michigan Fishes:* …fish ladders were built on all six of Consumers' hydros on the Au Sable River. …were it not for the failure of these same fish ladders to transport fish from the Lake Huron upstream into the Au Sable River (i.e., the dams effectively blocked upstream passage) that many of the exotic species (sea lamprey, round goby, etc.) that are of growing concern in Lake Huron would also be present in the Au Sable River upstream of Foote Dam (the lowermost hydro on the river)."

Response: First, the unimpounded river habitat represents poor habitat for most all of the exotic species (except sea lamprey) that are of growing concern in Lake Huron. With fish passage, these fish may be present in other portions of the system, but no significant populations would develop due to the river's cold-cool temperatures, relatively unproductive waters, and high-velocity characteristics (D. Jude, University of Michigan, personal communication). Sea lamprey would have to be blocked from river habitats upstream of Foote Dam. Second, Foote Dam is presently the only dam functioning as a barrier between Lake Huron and upstream reaches of the Au Sable River. Providing fish passage at upstream dams would not affect the integrity of Foote Dam as a barrier, would benefit the river's fish community, and should be pursued at other Consumers Energy dams on the river. Third, barriers such as those posed by these dams are largely responsible for the present rarity of several fishes (such as lake sturgeon and channel darter) and MDNR, Fisheries Division having to stock salmonids into Lake Huron to maintain the lake's fishery and the ecological balance between prey and predator fishes.

Comment: "second paragraph, *Effects of Dams on River Ecosystems:* The statement is made here that erosion due to the interruption of sediment transport and the excess energy present in flows downstream of dams 'produces channels below dams that are often unusually narrow or wide.' This statement is not supported by MDNR's own analysis presented in Table 5 where only one transect location was deemed to be too narrow (and this may be more due to the high discharge values that were apparently used in the calculation of expected widths)."

Response: The statements made in the text describe erosion that often happens downstream of dams. We agree that the data presented show no obvious alteration of stream width resulting from dam operations at Consumers Energy projects on the river.

Comment: "fourth paragraph, *Effects of Dams on River Ecosystems:* Here the observation is again made regarding a 1924 eyewitness account of peaking operations at Mio Dam and then a statement is made that 'recent peaking operations have been somewhat less frequent and dramatic.' Consumers is unclear as to what 'recent peaking operations' MDNR is referring to here relative to Mio Dam."

Response: This paragraph has been modified for clarification.

Comment: "sixth paragraph, *Effects of Dams on River Ecosystems:* Here MDNR makes observations concerning the effects of dams which maintain a constant water level above the dam. Consumers finds this criticism somewhat confusing given MDNR's standard requirement that hydroelectric plants be operated as run-of-river- plants (i.e., where outflow equals inflow). This required run-of-river operation results in a much more constant or steady water level in the pond compared to the historic minimum flow-peaking mode of operation which allowed the ponds to fluctuate on a daily and even seasonal basis, the lack of which is now being criticized here."

Response: This paragraph was primarily referring to lake-level control structures on natural lakes, and the wording has been changed from "ponds" to "lakes". We agree that daily stability of flows at outlets of lakes and ponds is important, but the intent of the paragraph is to stress the importance of seasonal and yearly cycles of water level fluctuation that naturally occur in lakes and wetlands.

Comment: "*Effects of Dams on River Ecosystems:* Here MDNR state that 'All large hydroelectric dams on the lower mainstem draw and release surface waters.' The four lower dams on the Au Sable River … have water intake structures, which draw water from at least the top two thirds of the water column. …This can hardly be considered a release of 'surface waters' as MDNR states here."

Response: The wording has been changed to reflect the comment.

Comment: "*Effects of Dams on River Ecosystems:* MDNR also states that FERC concluded that short-term cold water (<68°F) releases are a possibility at Mio and Alcona dams as part of FERC's environmental assessment (EA) in the relicensing of these two dams. In fact, FERC found that the potential for such a release was small owing to the small size and shallow nature of the ponds and the configuration of the hydro water intakes. Based on FERC's calculations the possibility of such a release of 'cool water' would be limited to about 80 hours (or a little more than three days) at each plant. The short term nature of such a release is also recognized in the second paragraph on page 49 of the Assessment, where MDNR cites FERC's calculation of the retention or storage time of the ponds, none of which is greater than 12 days."

Response: We agree that temperature modification below Consumers Energy dams on the Au Sable River may only occur for relatively short time periods each year, but we think that this may be worth pursuing because: 1) the key value and long-term fishery management goal identified for the Au Sable River is as a large, free-flowing, cold water river; 2) Consumers Energy dams clearly warm downstream reaches of the river; 3) any cooling of water temperatures below the dams would be beneficial to coldwater fishes inhabiting these reaches; and 4) the 1994 report by FERC said that this is a possibility below Mio and Alcona dams.

Comment: "MDNR is reminded that Consumers is in the final stages of the three-year water quality limits evaluation of its Au Sable River hydros as agreed to in the Settlement and adopted by FERC in its licenses. This evaluation will document water quality conditions attributable to the hydros and will also determine the feasibility of various mitigation techniques (such as the possibility of cold or cool water discharges at Mio and Alcona as stated in the previous paragraph). The results of this evaluation will be reviewed with the resource agencies and then filed with FERC."

Response: Comment noted. We look forward to reviewing the information being collected and discussing mitigation options.

Comment: "*Effects of Dams on River Ecosystems:* It is unclear to Consumers how its hydros prevent flying insects from migrating upstream as seems to be implied here."

<u>Response</u>: Some adult aquatic insects that require riverine (free-flowing) habitats cannot fly great distances. For such species, the presence of a dam and a large pond in the river may represent a barrier between upstream and downstream riverine reaches. The wording has also been changed in the text to clarify this point.

Comment: "*Effects of Dams on River Ecosystems:* Consumers is also unclear to the meaning of MDNR's statement in the final sentence of this paragraph where it says 'these altered habitats provide a foothold for lentic invaders in the watershed, such as zebra mussels.'"

<u>Response</u>: Populations of many invading aquatic species, such as zebra mussels, Eurasian milfoil, common carp, white perch, European ruffe, and round goby require lentic habitats to thrive. Without the ponds, the Au Sable River would be too cold, too fast, and too unproductive to allow populations of these species to reach high (or even moderate) levels. The ponds provide the closest thing to a warm, productive lake habitat that can now be found in the river system. For example, Foote Pond, relative to an unimpounded reach, provides zebra mussels with: still-water habitat that is more suitable for larvae colonization; a better source of phytoplankton for filter-feeding; and warmer (more suitable) water temperatures for growth. Without Foote Pond, zebra mussel populations in this river reach would probably be minimal to non-existent. Hence, "these altered habitats provide a foothold for lentic invaders". This point was also clarified in the text.

Comment: Effects of dams were "well documented, [providing] good basis for estimating long-term ecological potential of the Au Sable River without dams and the effects dams have had on the aquatic community".

<u>Response</u>: Thank you.

Comment: Because these hydros have operated since their initial construction without fish protection devices on turbine intake structures, the numbers generated from fish entrainment and mortality studies, and consequently the compensation for these losses, is based from an impacted fishery and do not represent true fish losses. The turbine intake structures need fish protection devices to allow the hydro reservoir fish populations to develop more fully.

<u>Response</u>: Your comment is noted, but the mitigation values for fish mortalities resulting from entrainment have already been agreed upon through the Settlement Agreement (see Appendix 1). We agree that fish protection devices would be beneficial to fish populations in the ponds, but the extent to which these populations can develop is limited due to the cool summer temperatures and high flushing rates of the ponds.

Comment: Paragraph 15, "*Effects of Dams on River Ecosystems:* Here MDNR talks about the supposed 'potential productivity' relative to chinook salmon and steelhead and suggests the 'fish passage and dam removal would greatly contribute to rehabilitation of the Au Sable River ecosystem' as if these two fish species were native to the Au Sable River when, in fact, they are exotic species introduced by MDNR." The primary benefit of fish passage or dam removal is to support non-native species.

<u>Response</u>: What would be restored is the river's ecological role as an important spawning area for many Lake Huron fishes. Quantitative estimates were made for chinook salmon, steelhead,

and lake sturgeon because data were available for making estimates for these species. Many native fishes would benefit from dam removal and fish passage including lake whitefish, round whitefish, lake herring, lake trout, burbot, walleye, lake sturgeon (state-threatened), greater redhorse, shorthead redhorse, silver redhorse, golden redhorse, longnose sucker, white sucker, smallmouth bass, and many smaller-bodied fishes. The statement that important naturalized sport fishes (e.g. chinook salmon, steelhead, and brown trout) would also benefit is correct.

Comment: "Smolt production estimates for existing conditions (with dams) may be too high, only accounting for habitat suitability of existing riverine reaches to produce smolts and not factoring in downstream mortality…"

Response: We acknowledge that a variety of factors would cause considerable mortality to fishes before reaching Lake Huron and have already discussed this (see **Fishery Management**). The estimates provided are simply based on habitat suitability and do not represent actual numbers of smolts entering Lake Huron.

Comment: "Impoundment fish population surveys have shown a variety of 'valuable lentic sport fishes' in the ponds, and although populations may be somewhat limited, they do exist and should be included in the list of species that follows that statement."

Response: A list of sport fishes in the ponds has been included.

Comment: "In the long-term, restoring the Au Sable to a free-flowing condition may provide a net benefit to wildlife resources as well as fisheries resources. However, there is not enough information included in the Assessment to clearly make that judgment."

Response: We think that the information presented in the Assessment provides a compelling argument for fish passage or dam removal and agree with your first sentence. We are unaware of any major wildlife-related issues on rivers that currently are accessible to Great Lakes fishes. We would appreciate more detailed comments regarding the type of information needed to allow your agency to make that judgment.

Water Quality

Comment: "The USGS collected water quality data at Rea Road for the period 1978 to 1994. …This data set should provide an excellent reference for future comparisons."

Response: Water quality sites were selected so that data from each site would generally characterize one mainstem valley segment along the river. The data you mentioned will be referenced in the future as needed.

Comment: Fourth paragraph, *General Water Quality, Point and Nonpoint Source Issues:* "The improper burning of propellant was considered training, not 'disposal'. This practice was stopped in 1993 and all contaminated sites were cleaned up according to MDEQ standards."

Response: Regardless of whether the activity was defined as "training" or "disposal", propellants were burned in an improper manner, creating a contaminated site. Comment regarding clean-up was added to text.

Comment: In fall 1999, a 5-year monitoring plan was initiated to assess potential impacts to surface waters, groundwater, and sediments surrounding the Range 40 complex.

Response: This was added to **Water Quality**.

Comment: More discussion is needed regarding the dangers of having a large military training facility in the headwaters of the Au Sable. "Surely the authors know of the extreme negative impact on the river's health caused by the National Guard facility in Grayling. I am personally disappointed that this major issue is so lightly addressed and it creates dark, suspicious thoughts."

Response: It is understood that a large military training facility has the potential to harm the headwaters of the Au Sable. As stated in the text, we have studied the findings of intensive studies done by consultants that were thoroughly reviewed by MDEQ, SWQD. These studies identified some contaminated areas, all of which have been cleaned up to the extent that current technology allows. Low levels of contaminants occur in certain areas, but they cannot be attributed to the river's current health and fish population levels. For example, brook trout, a very sensitive species, have maintained high population levels in the North Branch Au Sable River since the 1950s (Figure 24). Changes in brown trout population abundance in the North Branch Au Sable River (Figure 23) are probably due to factors (e.g. habitat changes or climatic factors) other than chemical contaminants. Due to the potential for future contamination events, continued monitoring of Camp Grayling activities is needed to ensure that the river's headwaters are protected from sedimentation due to unauthorized stream crossings and from soil, groundwater, and surface water contamination.

Comment: "Discussion is needed on the use of brine on the roads to control ice during the winter month and dust during the dry season. Crawford County has extensively used old brine well for these purposes, as well as selling product to Oscoda County for the same purposes."

Response: Brines were listed as a non-point source of pollution in paragraph 4, *General Water Quality, Point and Nonpoint Source Issues.* The effects of using brines vary with the source of the brine and how heavily it is applied to roads. Effects of brines used to melt snow would be expected to be greatest during initial spring melt period. County road commissions develop brine management plans, and plan implementation occurs with little to no state-level oversight (R. Shoemaker, MDEQ, SWQD, personal communication). The effect of brines on the river is poorly understood due to a lack of data. The need for more information has been highlighted in *General Water Quality, Point and Nonpoint Source Issues* and listed under **Management Options**.

Comment: Baseline data on urban runoff into our streams is needed. It's a well-known fact that all the storm water drains from the City of Grayling and the Village of Roscommon run directly into the river. Storm water retention is not mentioned in the draft. A full analysis is needed to determine these effects.

Response: Long-term discharge data is available for the mainstem at Grayling from the USGS for 1943-93. Berry (1992) conducted a thorough analysis of this data, suggesting that spring flows have been increasing in Grayling over the last several decades, possibly due to urban development. This is listed as a concern in the **Fisheries Management** section. Storm water runoff issues resulting from urban development are discussed extensively in **Soils and Land Use.** Several management options presented concern runoff, retention, and maintaining stable flows in the river.

Comment: "No mention of the Au Sable Canoe Marathon and its impact on the stream. We have documented turbidity levels showing a 10-fold increase in sediment being washed into the stream, due to the wake produced by racing canoes. The repeated practice runs and the associated wakes produced are worse than any single year high water event to the stream."

Response: We were not aware of the data you mentioned and would be interested in seeing it. Commercial canoeing has been added as a nonpoint source of sedimentation in *General Water Quality, Point and Nonpoint Source Issues.*

Comment: "And, let's not forget the farmers in Iosco and Alcona counties that are along the tributaries of the Pine River. Let's make a deal with them. They keep their cows out of the water and the DNR will keep the deer out of their fields. …this will keep the manure off the fish.."

Response: We agree that this is a concern and is listed in the **Management Options** section. Statements regarding this issue were also added to *General Water Quality, Point and Nonpoint Source Issues*.

Comment: Second paragraph, *Temperature and Dissolved Oxygen Issues:* "Consumers notes that the data referred to here is provisional…"

Response: The type of data has been changed to "unpublished provisional data".

Comment: Third paragraph, *Fish Consumption Advisories*: "PCB effects on other riparian dependent species (e.g. fish eating raptors, mink) should be documented along with PCB levels documented for fish if this data is available."

Response: PCB issues were discussed for birds in general, and for three riparian predators that feed extensively on fish: bald eagle, mink, and river otter (see **Fishery Management**). Trends in PCB concentrations in Great Lakes fishes were presented (Figure 18). We are unaware of any PCB trend data for other animals, and would have presented it if available.

Special Jurisdictions

Comment: *State and Federally Designated River Segments*: The 23 miles of Federal Wild and Scenic River are actually located downstream from Mio Dam (west boundary of T26N, R3E, section 8) to the upstream end of Alcona Pond (south boundary of T26N, R5E, section 28). This designated section of river has a Management Plan under the authority of the U.S. Forest Service.

Response: The changes have been made in the text. Comment regarding Management Plan was added to text.

Comment: *State and Federally Designated River Segments*: The correct mileage for State Natural Rivers in the Au Sable River watershed is 251. Building setbacks on the North and South branches of the Au Sable River are also 200, and setbacks on tributaries are 100 feet (not 150 feet). A 75-foot natural vegetation strip is required on private land on the North Branch and South Branch, and a 50-foot vegetation strip is required on tributaries.

Response: This has been incorporated into the text.

Comment: "*Major Public and Private Landowners:* It is interesting to note that the US Forest Service (owning 5% of the land in the watershed) and Consumers (owning 1% of the land in the watershed) both have comprehensive management plans which stress multiple use management of their affected lands whereas the State of Michigan (with the MDNR as land manager) as the majority land owner (32%) in the watershed does not have such a plan at the present time…"

Response: The comment is noted and we are encouraging MDNR, Forest Management Division to develop one. However, MDNR, Forest Management Division Compartment Review process allows for public, interest group, and agency comments into management of State of Michigan forest lands within the Au Sable River watershed.

Comment: "*Major Public and Private Landowners:* Our [Michigan Department of Military Affairs Camp Grayling] draft land management plan (INRMP, Integrated Training Area Management Plan) is intended to document our existing and proposed plans to protect natural resources and our agreements and cooperation with other agencies and organizations to participate in ecosystem-based management. Uncertain as to how useful it will be to Forest Management Division."

Response: Comment was incorporated into the text.

Comment: "Dredge and Fill Activities: Somewhere near the end of this discussion, you should include the statement, 'many of these activities are also subject to Natural River zoning ordinances and rules.'"

Response: Comment was incorporated into the text.

Biological Communities

Comment: "*Original Fish Communities:* Was any data collected at locations which were 'pre-impoundment'?"

Response: The only pre-impoundment collections made were those discussed in the text. However, these collections were all made from areas in the watershed upstream of Mio Pond. Aside from historic records of walleye, sturgeon, steelhead, grayling, and whitefish reported in the text, no pre-impoundment records are available for the river downstream of Mio Pond.

Comment: "*Modifying Factors:* MDNR makes numerous statements about the general effects of dams on fish migrations but provides no data from the Au Sable River to support the concluding sentence where it is stated that 'Dams in the Au Sable River system prevent the river from realizing it's potential to support thriving fish populations.' There is no data presented in the Assessment to indicate that existing fish populations in the ponds or river reaches in between ponds are limited due to a lack of habitat. The only fish populations that may be limited are the exotic Great Lakes fishes…"

Response: We think there is abundant evidence that the Au Sable River had thriving populations of resident fishes and runs of Great Lakes fishes before construction of Consumers Energy dams, and that the dams presently limit populations of many native fishes in the river. For example: 1) the Au Sable River's unique geology and high-gradient nature (see **Geology and Hydrology** and **Channel Morphology**) provided unique flow and habitat conditions important to many Michigan fishes; 2) runs of many native fishes were documented in the river, including species such as lake sturgeon, walleye, whitefishes, lake trout, yellow perch, rainbow trout (introduced), suckers, redhorses, and others (see **Biological Communities**)- significant runs no longer occur; 3) due to the obvious need for allowing fish to migrate upriver, fish ladders were required *by law* at all hydro dams at the time of dam construction (even though fish ladder technology did not exist) (see **Dams and Barriers**); 4) trap and transfers of fish past dams, including Foote Dam, occurred on many rivers for many years following dam construction (see **Dams and Barriers**; Fisheries Division records); 5) at present, populations of many fishes that use impounded habitats are greatly reduced and only remnant populations occur in existing portions of the river (e.g. state-threatened lake sturgeon, state-threatened channel darter, round whitefish); 6) today, little, if any natural reproduction of salmonids occurs in the mainstem below Mio Dam; 7) to support populations of sport fishes, such as brown trout, rainbow trout, and walleye, reaches of the river modified and fragmented by dams need to be stocked; 8) Lake Huron needs to be stocked with salmonids to replace natural reproduction of fishes that would have occurred in reaches now impounded (see **Fishery Management**); and 9) entrainment data show that fish still need to move throughout the river system. Even today, the fact that fishes congregate below dams during spawning times indicates that dams represent obstacles to natural migrations.

Comment: "*Current Fish Communities:* Consumers questions the usefulness and accuracy of the data and discussion presented here in that it is largely based on fish survey data collected in 1972 (almost 30 year old data). …Consumers believes that MDNR should collect current information on the biological communities of the Au Sable River for use in its river management planning activities."

Response: We agree that some of the data presented is dated, and point out that obtaining updated survey data is included as a management option (see **Management Options**). However, just because the data were collected in 1972 does not imply anything about its accuracy. The reason these data were presented along with more recent data on fish communities is that they tell a consistent story through time. That is, the upper portions of the watershed have continued to remain in a relatively unperturbed state to the present time, while the lower reaches of the river continue to show similar patterns of degradation associated with hydropower activities that were observed almost 30 years ago. The more recent data, (such as the surveys conducted for hydro relicensing) merely corroborate the patterns observed in 1972.

Comment: "*Threatened and Endangered Fishes:* Given the 34 years remaining on the operating licenses of the hydro dams, are there other actions with the dams in place to assist in the recovery of these species?"

Response: Properly designed fish passage structures have the potential to aid in the recovery of lake sturgeon. Stocking is also an option for lake sturgeon and was added to the **Management**

Options section. What may be the only additional suitable habitats for channel darter in the Au Sable River lie beneath Cooke and Foote ponds.

Comment: "The connection the fish communities have in the aquatic-riparian ecosystem merits mention (e.g. fish species which provide forage base for riparian dependent avian fauna such as raptors, great blue herons, and kingfishers)."

Response: We acknowledge that fish are eaten by a variety of birds, fish, and mammals, including humans.

Comment: "*Amphibians and Reptiles:* Nest predation (primarily raccoon) is one of the major threats to turtle species."

Response: Comment was incorporated into the text.

Comment: "*Amphibians and Reptiles:* What is the status and distribution of amphibians and reptiles (and their habitat) along the river?"

Response: Distributions by county of amphibians and reptiles in the watershed are shown in Table 21. We are unaware of more detailed, published inventories for these species within the watershed. This was listed as a **Management Option**. We would gladly receive any such information and incorporate it into future documents.

Comment: "*Mammals*: the Au Sable River provides suitable habitat for Indiana bat, a federally listed species."

Response: Comment noted. We are unaware of records indicating the species actually occurs in the watershed. We have tried to limit our discussion to mammal species known to occur within the Au Sable River watershed.

Comment: "*Pest species:* Mention should be made of purple loosestrife and Eurasian milfoil (either documented occurrences or potential habitat)."

Response: Comment was incorporated into the text. We are unaware of inventories for these species within the watershed. We would gladly receive any such information and incorporate it into future documents.

Comment: "*Pest species:* Not enough emphasis to bear out on the zebra mussel problem, which is more threatening to the Au Sable River system than the six hydro dams."

Response: The zebra mussel problem is a direct result of the presence of dams on the river, which create suitable habitat. There is really nothing that can be done to remove them from the hydro ponds.

Comment: "Round whitefish were found below Mio Dam…"

Response: Comment noted. This is known and shown on species distribution maps.

Comment: "*Pest Species:* Consumers notes that, by MDNR's definition given here, the Great Lakes fishes they repeatedly talk about passing upstream of the hydros would be considered 'pest species,' given the significant threat they pose to native species and their habitats. Consumers also notes that MDNR accurately recognizes the value of Foote Dam in stopping the upstream migration of sea lamprey into the Au Sable River."

Response: We are unsure about which Great Lakes fishes are being referred to as pests and the type of "significant threat" they pose. Many native fishes would benefit from dam removal and fish passage including lake whitefish, round whitefish, lake herring, lake trout, burbot, walleye, lake sturgeon (state-threatened), greater redhorse, shorthead redhorse, silver redhorse, golden redhorse, longnose sucker, white sucker, smallmouth bass, and many smaller-bodied fishes. In addition, many valuable, naturalized fishes, such as rainbow trout (steelhead), chinook salmon, and brown trout would also have access to spawning habitats in the river. These naturalized fishes are prized by millions of anglers in the Great Lakes region, are presently stocked by MDNR, Fisheries Division, and perform the important ecological function of suppressing Lake Huron's alewife population. We acknowledge that Foote Dam is an effective barrier against sea lamprey, but also point out that effective sea lamprey barriers can be constructed that are not 39 feet tall. Finally, fish passage structures can be built at projects upstream of Foote Dam that would benefit Au Sable River fish populations, and not affect the integrity of Foote Dam as a barrier to sea lamprey.

Fishery Management

Comment: "Key values- management should also work towards working with the existing biological communities associated with the hydro dam system given that this system will be in place at least 34 more years."

Response: We identified cold water riverine habitat as the key value for the Au Sable River because of the river's unique geological setting, its extremely stable, groundwater-dominated flow regime, and its high-gradient habitat. We agree to manage fish communities in the ponds to their biological potential, but did not identify them as a key value due to their limited fishery management potential and their effect on the lower mainstem.

Comment: "From a wildlife [MDNR, Wildlife Division] perspective, the Assessment is lacking in its treatment of birds and mammals. This is not unexpected, considering the presumed charge of the writers was to describe the condition and potential condition of the watershed as it relates to the fisheries resource. The clear message of the Assessment, removal of most dams on the Au Sable River, would result in a major change to this large, important body of water. In the long-term, restoring the Au Sable to a free-flowing condition may provide a net benefit to wildlife resources as well as fisheries resources. However, there is not enough information included in the Assessment to clearly make that judgment. …An unbiased scientific examination of available information is warranted to conclude that the proposed course will not harm wildlife health. Current use of the river system by vertebrates other than fish should be assessed and then the impact of the proposed changes projected…"

Response: We agree that an ecosystem-based assessment of the entire watershed would have greater treatment of birds and mammals. We also agree that an unbiased scientific examination of the effects of fish passage on wildlife species is the next appropriate step in developing a DNR-level position on fish passage in the Au Sable River. Given the potentially great benefit to the aquatic resources of the river, we think this issue should be given high priority and pursued jointly by MDNR Fisheries and Wildlife divisions, in cooperation with MDEQ, Surface Water Quality Division.

Comment: "Consumers wishes to note that even a casual inspection of Table 7 will show that almost all of the entrained fish are cool-water or warm-water species found primarily in the lentic environments behind the dams and are not the coldwater, lotic species that are the focus of MDNR management. This Assessment, in essence, provides no management options for the fish in the impoundments..."

Response: Almost all of the entrained fish are coolwater or warmwater because the dams and ponds have eliminated nearly all the cold water habitat (and coldwater fishes) that formerly occurred in this portion of the river. Additional management direction and options for Consumer's Energy ponds are included in the **Fishery Management** section.

Comment: The section on "Fishery management of the mainstem impoundments could use some strengthening….What changes could be made to hydropower operations to also enhance the impoundment sport fisheries?"

Response: More information and direction regarding fishery management of the impoundments is included in the **Fishery Management** section. Hydropower operational changes that could be made are limited to what is allowed by the Settlement Agreement (**Appendix 1**). Fish passage and fish protection devices at dams would allow greater movement of fishes between pond and river habitats, and reduce entrainment mortality. Both actions would clearly benefit fish populations.

Comment: "The majority of the shorelines of Loud and Five Channels ponds is within National Forest ownership."

Response: Comment was incorporated into the text.

Comment: "MDNR Fisheries Division overstates the damage caused to the impoundment fisheries resource by the dams, but provides no basis as to what these numbers might mean with regard to the populations of these species or the health of the impoundment fisheries. The Assessment then goes on to state that the damage estimates should also include the benefits foregone to coldwater species that would thrive in these environments if the dams were only removed. In fact, the removal of the dams would result in the almost complete loss of the impoundment fisheries resource that is the source of this entrainment data."

Response: The entrainment data is simply a presentation of raw (unembellished) data from entrainment studies that provided a basis for the Settlement Agreement reached between Consumers Energy and other agencies. We did not make any judgments regarding the extent to which impoundment fish communities are affected by entrainment. Such judgments would be very difficult to make without fish population estimates for the ponds. Regarding the final sentence in the comment–given that the key value for management of the Au Sable River is as a cold water, free-flowing river, Fisheries Division would gladly entertain options for replacing present impoundment fisheries (and their entrained fishes) with world-class, coldwater riverine fisheries.

Comment: "The publishing of these numbers to represent or imply damage to fish populations or to the ecosystem is perceived as disingenuous, given MDNR Fisheries Division's considerable efforts to reduce many of these same 'rough fish' populations (see last paragraph at page 73) and their apparent ultimate management goal of eliminating these populations altogether and replacing them with cold-water or cool-water riverine fish populations through the removal of dams."

Response: Fisheries Division has identified cold water, free-flowing river habitat as the key value of the Au Sable River. If this is achieved (i.e. dams are removed), fishes best adapted to the river will thrive, entrainment will not occur, and fish populations should be self-sustaining without active management. Since Consumers Energy ponds may remain for at least 34 more years, active near-term management is needed and has occurred. One near-term management action for Consumers Energy ponds is preventing unnecessary entrainment mortality at hydropower facilities. This would improve success of fish stocking actions in ponds where entrainment mortality is considerable (see **Fishery Management**). Eliminating unnecessary entrainment may also move the fish community toward achieving the biological potential of each water body. As the comment stated, selective removal of rough fishes (carp, bullhead, bowfin, and suckers) to promote sport fishes (a technique which worked on some Michigan lakes) was attempted on Mio Pond, but was eventually abandoned because existing habitat conditions overwhelmingly favored rough fishes.

Comment: "Because these impoundment fisheries are not highly valued by MDNR Fisheries Division, data on their exploitation and recreational value have not been calculated, as they have for salmonids in the riverine reaches above Mio and for the anadromous salmonids in the 10.2 miles below Foote Dam, where limited holding water and high fish numbers have produced a fishery reported to be worth $1,814,146 in 1987, or $177,877 per mile for the anadromous reach. It is expected that the high dollar value per river mile is an artifact of the limited length of the riverine reach below Foote Dam and could not be maintained at even a small fraction of the stated value if the accessible reach were extended upstream through either fish passage or dam removal."

Response: The resources of Fisheries Division are too limited to allow assessment of all lakes and rivers in Michigan. The lack of such data for the Consumer Energy ponds is not at all unusual. Creel census data for inland lakes is extremely rare. Fortunately, data were available for the Au Sable River downstream of Foote dam through an ongoing Fisheries Division Great Lakes creel survey. Survey data for 1999 have recently become available for Great Lakes accessible portions of the Au Sable, Manistee, and Muskegon rivers. Based on 1999 creel census data, angler trips per mile and number of miles for the Great Lakes accessible portions of the three rivers were: Au Sable–7597 angler trips per mile (10.2 river miles); Manistee–5875 angler trips per mile (25 river miles); and Muskegon–2308 angler trips per mile (46 river miles). These data show that shorter river reaches do tend to concentrate fishing intensity. However, these data also show that intense levels of fishing can occur on all Great Lakes accessible streams, and that considerable fishing pressure is maintained even over long stretches of river. The 1986-88 average of 3168 angler trips per mile on the river below Foote Dam is much lower than the 1999 data, and appears to be a conservative value compared the 5875 trips per mile estimated for 25 miles of the Manistee River. Given that the lower Au Sable River would provide better (higher gradient) habitat than the Manistee River, an undammed Au Sable River may support as much or more angler use than occurs on the Manistee River. Therefore, applying angler pressure estimates from reaches below Foote Dam to upstream areas seems reasonable. The value of an angler trip ($54) has been established from many studies of recreational angling and is commonly used to place economic values on fisheries.

Comment: “As impressive as these figures are for the anadromous resource, Consumers notes that if one used the same value of $54 per angler day and applied this to the approximately 600,000 user days of fishing on the six hydro impoundments then the value of that use is estimated at over $32 million annually or almost 18 times the value of the 1987 anadromous run below Foote Dam. Even if one assumed a lower value per angler day for the impoundment fishery, its total dollar value is still probably to significantly exceed that of the anadromous run below Foote Dam. The fish in Consumers' six Au Sable River ponds are of great economic value and should be a chief consideration in the MDNR Fisheries Division's development of either a fisheries management plan and/or comprehensive river management plan. It should also be noted that this does not account for the value associated with the many other uses of the hydro impoundments for camping, swimming, boating and water skiing, etc. as documented in Consumers' past recreation use studies. (Insight Marketing, Inc. 1993).”

Response: The long-term ecological health of the river system is the focus of the assessment, not the economic value of fisheries. This document shows conclusively that Consumers Energy hydroelectric projects are detrimental to the river’s ecological health. The estimates of recreational use of the Consumers Energy ponds, from the Insight Marketing, Inc. (1993) study, have been discussed in the text (see **Recreational Use**). Differences between estimates from this study and more intensive surveys by Fisheries Division suggest that the Insight Marketing, Inc. (1993) recreational use estimates, at least for fishing, appear to be overstated. However, if these data are used, they show that angler use in the short tailrace reaches (570,000 user days) is nearly equal to that of the larger ponds (605,000 user days). These data suggest a minimal trade-off from an angler use perspective, and further support rehabilitation of the river’s ecological health through dam removal, or to a lesser degree fish passage. Finally, other forms of recreation (e.g. camping, swimming, etc.) were not discussed due to a lack of quantitative data for the lower Au Sable River. The predominant types of recreation differ between ponds and free-flowing rivers, but both have considerable recreational value.

Comment: “*Potential for Improvements to Sports Fisheries:* The discussion of potential improvements to sports fisheries that could result from dam removal or fish passage is absolutely one-sided. The potential benefits are listed, but there is no mention of detriments. There is no mention of the high potential for the invasion of several exotic species and fish diseases that could annihilate local fish populations, nor is there any mention of the impact that exotic salmonids have on native fish populations, their habitat, or even the benthic community. For example, Krueger and May (1991) discuss such impacts in detail, including, but not limited to, competition, predation on native salmonids and other fishes, introduction of diseases and parasites, direct and indirect genetic effects on salmonids and other native species, and substrate modification due to the digging of reeds that affects spawning by native species and may severely impact benthos.”

Response: We disagree. Detriments of fish passage are discussed in considerable detail in a separate section (*Considerations Regarding Upstream Passage of Great Lakes Fishes* in **Fishery Management**). The comment of local fish populations in rivers being “annihilated” by introduced exotic species from the Great Lakes is not substantiated by facts. Many Michigan rivers are open to migrations of Great Lakes fishes and other exotic species, and in no case has a local fish population been annihilated. Local fish populations continue to thrive in these rivers.

However, dams on the Au Sable River have totally annihilated upstream runs of many native Lake Huron fishes including lake sturgeon (state-threatened), lake whitefish, round whitefish, lake herring, lake trout, burbot, walleye, greater redhorse, shorthead redhorse, silver redhorse, golden redhorse, longnose sucker, white sucker, smallmouth bass, and many smaller-bodied fishes. In addition, upstream dams within the river system totally block movement of resident fishes and continue to kill substantial numbers of resident fishes (see **Dams and Barriers**). Krueger and May (1991) generally discuss findings of studies of introduced fishes from different rivers throughout North America. Most all of these studies report on interactions (mostly during early life history phases) between naturally-reproducing, native and naturalized populations of salmonids. None of the effects discussed in the comment are of significant concern on the Au Sable River, because there is essentially no natural reproduction of salmonids in the river's mainstem below Mio dam. Any significant concerns regarding such issues on the Au Sable River would have been discussed in the text. Finally, to see severe affects to benthos, the reader is referenced to Figures 25, 26, and 27, which show the influence of Consumers Energy projects on invertebrate species richness and density.

Comment: "Little or no mention is made of the contaminant burdens in these anadromous fish and the hazard they pose to other fish and wildlife and their predators or even human consumers. Whole fish PCB concentrations in Au Sable River anadromous runs exceed the Great Lakes Water Quality Agreement Objective to protect fish and wildlife of 0.1 ug/g by a factor of 7 to more than 20, and 2, 3, 7, 8 TCDD dioxin equivalents exceed safe concentrations for fish and wildlife by a factor of about 20. (MDEQ 1999). Fish and wildlife are exposed to the live fish, dead and dying Pacific salmon, and their eggs, which are significantly higher in contaminant concentrations than the fish flesh due to their high lipid content and the lipophilic nature of PCBs and dioxins. In fact, Merna (1986) reports Chinook salmon eggs from Manistee and Muskegon River Chinooks averaging more than three times the total PCB concentration in the same fishes' salmon fillets. The ingestion of these eggs by stream rainbow trout resulted in the transfer of PCBs to the trout. Several trout fillet PCB concentrations actually exceeded the PCB concentration in the salmon fillets, and some even exceeded the FDA and Michigan standard of 2.0 mg/kg for human consumption. They exceeded the 'Uniform Advisory' standard of 0.05 mg/kg PCB by a factor of more than 40. This transfer and biomagnification of PCBs in the food chain resulted from salmon with PCB contaminant concentrations comparable to salmon found in the Au Sable River below Foote Dam."

Response: We support reductions in contaminant levels of Great Lakes fishes. The effects of contaminant burdens were discussed in detail (see *Fish Consumption Advisories* in **Water Quality** and *Considerations Regarding Upstream Passage of Great Lakes Fishes* in **Fishery Management**). We also point out that the findings of the study by Merna (1986) are dated and substantial changes in water quality have occurred in the interim. Contaminant levels have changed substantially since 1977-78, when Merna's data were collected. For example, PCB levels in Great Lakes fishes, such as lake trout, have dropped four-fold (Figure 18). Total PCB concentrations in all Lake Huron chinook salmon have been < 1.5 mg/kg since 1983, well below the FDA and Michigan standard of 2.0 mg/kg for human consumption. Use of old data, such as Merna (1986), to support positions against fish passage issues when more current data are available is misleading.

Comment: "The 'tremendous potential' for expanding potamodromous fisheries, chiefly exotic Chinook, coho, and steelhead salmon but even native species such as walleye also has the potential for significant harm both to the fauna of the Au Sable River watershed and the Great Lakes. If realized, smolt production as depicted in Table 8 could destabilize the Lake Huron ecosystem."

Response: Fish communities in restored lake and stream ecosystems do not need to be maintained by stocking fish. Fish passage and dam removal would reconnect the Au Sable River to Lake Huron, moving the Lake Huron ecosystem closer toward rehabilitation. Table 8 shows one way the Au Sable River could contribute to rehabilitation of the Lake Huron ecosystem. That way is to produce fish that are now stocked into the lake. In addition, populations of many other fishes would be bolstered through access to additional spawning rapids in the river. The estimates shown in Table 8 are for early life stages of fishes that MDNR, Fisheries Division now spends money to raise and stock into Lake Huron. Many of these fishes would have to survive long migrations, and some would spend an additional year or more in the river, before to reaching Lake Huron. As mentioned in the text (*Potential for Improvements to Sport Fisheries* in **Fishery Management**), substantial mortality (due to factors such as high summer temperatures, over-wintering, and predation) would occur before they reach the lake. Therefore, the numbers presented in Table 8 do not equate to numbers of fish entering Lake Huron. A similar situation occurs in Ontario tributaries to Lake Huron. Millions salmonids are presently produced in many, undammed Lake Huron tributaries in Ontario, but the actual numbers of those surviving to contribute to Lake Huron salmonid populations is much lower due to these sources of mortality. Whether or not the Au Sable River would actually provide enough salmonids that Fisheries Division would no longer have to stock Lake Huron is unclear.

Comment: "…the reported value of the potamodromous fishery below Foote Dam stated in Fishery Management, paragraph 26 differs from the value stated in Fishery Management, paragraph 21."

Response: The value in paragraph 21 was for one year while the value in paragraph 26 was a 3-year average. This was clarified in the text.

Comment: "*Potential for Improvements to Sport Fisheries*: The recreational fishery value is moderate to high on some of the impoundments at this time. Even with the somewhat limited potential for fisheries on the ponds, people do fish them which has some associated economic value."

Response: As was stated in paragraph 5, *Potential for Improvements to Sport Fisheries,* "The potential recreational and fish production benefits of dam removal or fish passage need to be weighed against the value of the existing fishery and costs for dam removal or fish passage devices. The value of the existing fishery between Mio Pond and Foote Dam is unknown and needs to be estimated." Existing data from Insight Marketing, Inc. (1993) may be inadequate for doing this (see **Recreational Use**).

Comment: Return to peaking flows below Foote Dam will eliminate sediment buildup in the lower river, increase catches of anadromous strains (steelhead, chinook salmon, and walleye), and allow for easier boat navigation in the river.

Response: Sediment buildup in the stream resulted from shoreline erosion due to past peaking operation. Fishing and boating problems due to the buildup have been exacerbated in recent years, mostly due to drought conditions (resulting in reduced stream discharge) and low Lake Huron water levels. Angling opportunities are still good on the river below Foote Dam, but angling patterns have changed to mimic more natural variations in flow patterns. Data from a Fisheries Division creel survey done in 1999 indicated much higher catches of Great Lakes salmonids downstream of Foote Dam than occurred in the late 1980s (Fisheries Division, unpublished data).

Comment: "Wouldn't the addition of woody debris be cheaper than dam removal."

Comment: Woody debris addition will not solve the main problems on the river, namely loss of cold water habitat due to warming by ponds, loss of high-gradient rapids, and loss of connections within the river system and to Lake Huron.

Comment: "*Some Economic Trade-offs of Removing Dams on the Au Sable River:* The economic data provided for the costs and benefits of fish ladder construction or for dam removal are completely inadequate for objective economic evaluation of alternatives or even to support any discussion of alternatives."

> Response: These were the only data available. We would like more accurate estimates of the cost of fish ladder construction and dam removal at Consumers Energy projects for use in future discussions.

Comment: " *Some Economic Trade-offs of Removing Dams on the Au Sable River:* The economic benefit of other types of recreation on the hydro-electric impoundments needs to be quantified for any economic comparisons between existing conditions and dam removal scenario"

> Response: River-related recreational use information has been added to the **Recreational Use** section. We agree that economic comparisons between existing conditions and dam removal scenarios would aid in future planning.

Comment: "Consumers notes MDNR's references to a number of dollar figures from FERC staff's environmental assessment of the relicensing of Consumers' six hydros. As is often the case with any analysis that tries to forecast the future, the actual results are often drastically different from those that are forecast. The figures identified in your Assessment do not reflect the realities of the electric utility industry today. This is largely due to the trend toward the deregulation of the electric utility industry and its impact on the market price of electricity. As a result, the figures quoted here have very little relevance in today's world and should be deleted from the Assessment."

> Response: The data used were only published data available at the time. We agree that Consumers Energy needs to continually examine the cost-effectiveness of its hydropower facilities on the Au Sable River in light of the environmental costs they incur.

Comment: "Second paragraph, *Considerations Regarding Upstream Passage of Great Lakes Fish:* Figure 18 is from DeVault 1996, as stated on the figure, not Day (1997)."

> Response: Day (1997) provided additional supportive data for the statement.

Comment: "Given that PCB concentrations in Great Lakes fish have not declined since the mid-1980s (MDEQ 1998), there is no reason not to use Consumers' 1990 whole fish PCB data and the assessments, based in part on this data, for comparison to the above criteria and for establishing the hazards to fish and wildlife posed by Au Sable River anadromous fish. …Hazard assessments (Giesy et al. 1994b, 1995) clearly demonstrate the hazard posed by PCBs and related 2,3,7,8 TCDD-EQ toxicity to mink and eagles."

Response: The hazard assessments funded by Consumers Energy were used in this document (see *Considerations Regarding Upstream Passage of Great Lakes Fishes* in **Fishery Management**). As we stated in the text, the findings of these hazard assessments need to be interpreted cautiously because they are not supported by field observations. For example, the assessments suggest that Great Lakes fishes pose a clear hazard to bald eagle populations, despite increases during the last 15 years in reproductive success of bald eagles foraging along the Great Lakes and anadromous streams (Figures 33 and 34; Bowerman et al. 1998).

Comment: "Gross productivity [of bald eagles] is only one measure of reproductive performance, albeit the one most easily measured. Given the concentrations of PCBs and dioxin equivalents in bald eagle eggs and fledglings in Great Lakes-influenced locations, including anadromous streams, these birds may never participate in the eagle gene pool. Overtly, there has been an increase in the rate of eagle deformities in Michigan as DDE concentrations have fallen, resulting in increased hatching success, and PCB and dioxin-mediated deformities have been allowed to express themselves. (Bowerman et al. 1998)."

Response: Gross productivity is easily measured and is probably one of the most meaningful measures of bald eagle reproductive health. Unlike other measures of contaminant concentration used to infer reproductive success, gross productivity directly measures it. The usefulness of indirect measures to infer reproductive success should be questioned because they may not be correlated with direct measures of reproductive success. For example, Bowerman et al. (1998) found no trends in PCBs or DDE in eggs of bald eagles nesting along the Great Lakes even though a very clear increase in reproductive success was observed during this time period.

Despite inferences that Great Lakes-influenced eagle populations are impaired (Bowerman et al. 1998), data on reproductive success show they are reproducing at stable (>0.7 fledglings per nest) or healthy (>1 fledglings per nest) rates as defined by the U.S. Fish and Wildlife Service (see **Fishery Management**). Increasing rates of eagle deformities (Bowerman et al. 1998) are very slight, and are subject to effects of small sample size and how the data were analyzed (e.g. Bowerman et al. (1998) compare a 22-year average deformity rate with a 6-year average deformity rate). Deformity "rate" data also need to be put into perspective. For example, between 1990 and 1995, 6 deformed eagle nestlings were observed in Michigan out of over 1300 birds fledged. At least 2 deformed nestlings occurred along the Raisin River in southeast Michigan. As Michigan's bald eagle population expands and reproduces in new areas, such as more industrialized southeast Michigan, increased frequency of deformities may not be surprising.

Comment: "The recovery of the bald eagle population along the Great Lakes is most likely due to immigration of relatively uncontaminated adults from interior regions (Bowerman et al. 1998)… …Both productivity and the concentrations of environmental toxicants in eggs can be influenced by the immigration of breeding adults from less contaminated interior regions. …While Great Lakes shoreline eagles do eat a higher percentage of birds, especially gulls, that are higher in the food chain and thus higher in contaminant concentrations than fish, the increase in productivity of Great Lakes nests is not particularly remarkable when one take substantial immigration of essentially uncontaminated breeders from the interior into account. '… These younger, less contaminated birds mask the effects of environmental contaminants within this population since it takes a few years of exposure for these… effects to become evident.' (Giesy et al. 1995)."

Response: Statements of "substantial immigration" are not supported by any data Bowerman et al. (1998) present, and do not explain increased reproductive success of bald eagles nesting along

Great Lakes-influenced shorelines and rivers. If “substantial immigration” were occurring, then given that the fledgling success of bald eagles nesting along Great Lakes-influenced shorelines and rivers has been increasing since 1961 (when data collection began) and is now approaching that of inland bald eagles (Bowerman et al. 1998), one has to wonder when we will see the effect of contaminants that have been building up in the supposed “immigrant” bald eagles that have nested for so many years along Great Lakes-influenced shorelines and rivers.

Comment: “Food is indeed the most important factor in eagle production, although food that contains significant contaminant concentrations also negatively affects young vertebrates and may affect their long term viability and fitness. Both total PCB and TCDD-EQ in Au Sable River Great Lakes-influenced fish are sufficient to pose a significant hazard to bald eagles. (Giesy et al. 1995). Whole fish Au Sable River Chinook salmon PCB concentrations average 1.7 ug/g, as compared to a ‘lowest observed adverse effect level’ (LOAEL) of 0.067 ug/g and a ‘no observed adverse effect level’ (NOAEL) of 0.00068 ug/g. This concentration is 25.4 times the LOAEL and 254 times the NOAEL. (Sprunt et al. 1973). Consumers concurs with the US Fish and Wildlife Service recommendation that, prior to considering fish passage, ‘contaminants of concern must be lowered to acceptable concentrations (No Observable Adverse Effect Concentrations in the most sensitive species) in eagle eggs and fish (based on biomagnification factors from fish to eagle eggs) used as food for eagles.’ (Sprunt et al. 1973). MDNR Wildlife Division has concurred with this approach; MDNR Fisheries Division has noted that it does not concur.”

<u>Response</u>: The NOAEL models have been intensely scrutinized from the beginning. Their value has been questioned, particularly because existing field data (e.g. data on bald eagle reproductive success) does not support model predictions. For example, Bowerman et al. (1998) found no trends in PCBs or DDE in eggs of bald eagles nesting along the Great Lakes, even though a very clear increase in reproductive success was observed during this time period. MDNR, Fisheries Division does not agree with the approach of using NOAEL values as decision criteria on fish passage issues. The question of MDNR, Wildlife Division support for using NOAEL values as decision criteria is unresolved.

Comment: “With regard to the Wellston nest, you should be aware that it is located upstream of Tippy Dam and that only a portion of its forage base can be attributed to the Great Lakes-influenced reach. Telemetry studies during relicensing indicated that forage during critical early stages of the nesting period was obtained exclusively from the Pine River delta area above Tippy Dam. Additionally, you should also be aware that this territory produced no young from 1994 through 1998, which would have had a significant impact on Rozich's calculation had he obtained the most recent data.”

<u>Response</u>: Comment noted. Unfortunately, we do not have access to specific details regarding the Wellston nest, though the latest data we have suggests it averaged 1.22 fledglings per year for 1988-96. Since the Wellston nest is close to Tippy Dam, maybe the Pere Marquette nest would be a better example of a nest located entirely along a Great Lakes–influenced river. It averaged 1.88 fledglings per year from 1989-96.

Comment: Paragraph 3, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: “Our records indicate that the Whelan Lake nest has not been active since 1965. The Pere Marquette River does support one bald eagle breeding area, known as the Pere Marquette River breeding area, and perhaps this is the nest you intended to refer to. Also by definition, the Wellston nest is not in an anadromous location, but instead an inland site."

> Response: The data we used was for the Pere Marquette River nest, not the Whelan Lake nest. This correction has been made in the text. The anadromous classification of the Wellston nest is what is used by MDNR, Wildlife Division, so we did not change its class.

Comment: "The removal of dams may provide better winter habitat for eagles foraging for fish along the Au Sable River, but the free-flowing river would provide inferior foraging habitat and inferior nesting and brood raising habitat for eagles during the ice-free season. White sucker, northern pike, and bowfin in the impoundments provide a seasonably abundant, uncontaminated food supply for eaglets in the preferred lentic foraging habitat."

> Response: The statement that free-flowing rivers provide inferior foraging habitat, nesting, and brood raising habitat is unsupported. Many eagle nests occur on rivers, and their levels of fledgling success of bald eagles nesting along rivers (including Great Lakes – influenced rivers) are comparable to those nesting on lakes. In fact, the highest concentrations of bald eagles in the United States occur along rivers with salmon runs. Studies, such as Stalmaster and Gessamen (1984) suggest that winter food shortages can limit eagle populations. Winter ice-cover on the six Consumers Energy dams on the lower mainstem limits the amount of winter foraging habitat available to bald eagles along the river. Removal of dams on the lower mainstem would result in more ice-free, winter foraging habitat and increased spawning runs of Great Lakes fishes. Therefore, dam removal could potentially provide greater foraging opportunities for bald eagles.

Comment: "The ponds provide more bald eagle foraging habitat than open riverine sections of the Au Sable."

> Response: Not during the winter. Many eagles nest and forage along rivers during all seasons.

Comment: "With regard to the discussion of potential impacts on mink and otter [paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes* in **Fishery Management**] Wren, writing in 1991, would likely have come to a different conclusion today. All of the other references you cited relative to the causal relationship between mink reproduction and the exposure to organochlorine chemicals were written after Wren's paper."

> Response: Wren (1991) was referring to population levels at a larger spatial scale (states), and was not referring to reproductive success of individual animals. The second sentence of the paragraph in question states that "mink are extremely sensitive to organochlorine chemicals".

Comment: Paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "With regard to your second observation, it is not at all inconceivable that mink would eat a 100% fish diet if the fish were readily available, especially during the winter months (Reis 2000). Dead salmon and steelhead are available in the Au Sable River below Foote Dam from October through April and offer a convenient, easily accessible food source for mink. Stalmaster and Gessaman (1984) document the persistence of salmon carcasses over the winter in riverine systems."

> Response: We stated that care should be exercised in interpreting studies by Heaton et al. (1995a and 1995b) partly because the average daily diet of mink would probably not consist "solely of

one species of fish", and did not make any reference to a "100% fish diet" as the comment states. Fish composed an average of only 29.7% of a wild mink's diet based on findings of seven published studies (Heaton et al. 1995a). Consequently, assuming that wild mink would eat a 100% fish diet may be unrealistic, and a mink's eating a 100% diet of one species of fish seems even more unrealistic.

Comment: Paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "…Your statement that, without the safety factor of 10, these fishes would be safe for consumption is inaccurate. Both Au Sable River Chinook salmon (HI=2.36) and walleye (HI=2.9) would exceed an HI of 1 based on Heaton's (1992) LOAEC of 0.72 mg/kg for a diet that included only 10% fish. Only Au Sable River white sucker would achieve an HI of 1.0 or less. …Giesy et al. (1994a) apparently erred in using 0.072 mg/kg as the NOAEC. Based on Heaton's (1992) data, this should have been the LOAEC for a 100% fish diet. The NOAEC should presumably have been 0.0072 mg/kg total PCB."

Response: Apparently Heaton's (1992) LOAEC of 0.72 mg PCB per kg was incorrect, because their more recent, published paper (Heaton et al. 1995a) used a revised LOAEC of 0.16 mg PCB per kg. Our statement is accurate, based on the more recent studies.

Comment: Paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "The use of the factor did not cause the fish to become unsafe; the contaminants did. Even if a single fish is considered safe for consumption without the use of the safety factor, eating many such fish could be detrimental to growth and productivity of individuals that consume the fish."

Response: The studies done were based on animals eating a diet of "many such fish". Bald eagles in the wild are now eating many fish and their populations appear to be doing quite well based on current data.

Comment: Paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "As pointed out above, salmon and steelhead are in the Au Sable River from at least October through April."

Response: Comment was incorporated into the text.

Comment: Paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "The argument that carp are not particularly available to mink along the Au Sable is moot in that carp were not among the species analyzed by Giesy et al. (1994a) for the Au Sable River."

Response: We were not referring Giesy et al. (1994a), but rather to studies by Heaton et al. (1995a and 1995b). This has been clarified in the text.

Comment: Paragraph 4, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "You also state that 'Giesy et al. (1994a) estimated that the fishes below Foote Dam could comprise roughly 30% of the mink diet before the PCB hazard index values were exceeded'. In fact, the paper makes no reference in this regard to the fishes below Foote Dam…"

Response: We disagree. Our statement is clearly depicted in Figure 1 of Giesy et al. (1994a), which is entitled, "Percent of fish, based on the average concentrations of mercury, PCBs, and

TCDD-EQ in all species combined collected at each location, which would be allowed in the mink diet so as to not exceed a hazard index of 1".

Comment: Paragraph 5, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "You note that Kotanchik (1997) identified a section of the Rifle River that is open to potamodromous runs as having one of the two highest otter populations in the state, and the Pine River open to potamodromous runs as having otter populations comparable to those on the upper Au Sable (last paragraph at page 80). If this is true, and these figures are not artifacts of the sampling methods, we would suggest that these otter populations owe their abundance not to the anadromous run but rather to the numerous beaver dams on these streams that both block the passage of anadromous fish to the many tributaries and provide preferred habitat for otter foraging (Field 1970)."

Response: We know that salmon reproduce in these streams, and that they sometimes move through beaver dams to reach spawning streams. Our point was that otter appear to be abundant in these areas despite the presence of salmon, not because of them.

Comment: "Wren (1991) and many others have commented on the disappearance of mink and otter from the Great Lakes shorelines and anadromous streams (first paragraph at page 81). In the course of gathering data on wildlife populations to support the relicensing of Tippy and Hodenpyl dams on the Manistee River, Consumers' ecological consultants obtained some fairly direct evidence linking salmon to the demise of a mink population. Tippy Dam is located at river mile 31 on the Manistee River. Between Tippy Dam and the mouth of the river at Lake Michigan are extensive wetlands, including those of the Manistee State Game Area. These wetlands include a preponderance of emergent wetlands that harbor abundant muskrat populations and that formerly harbored an abundant mink population as well."

"As part of the wildlife population studies, Dow, Ebbers, and Evers (1991) interviewed Mr. Paul Johnson, a trapper and fur buyer from Mesick, on the status of furbearers in the region. With regard to mink, they state the following: 'The Johnsons also buy fur from trappers downstream of Tippy Dam, an area that formerly contained an abundant mink population. The two or three trappers working in that area no longer find mink along the mainstream, and thus concentrate on tributaries instead, where only a few are harvested despite intense trapping effort. These trappers reported to P. Johnson that mink along the mainstream began disappearing after the first of the big coho runs, a time when numerous mink were frequently seen feeding on dead salmon. The initial decline was rapid, over a span of several years, and the population has apparently never rebounded.'"

Response: Unless there is actual data to support the comment, it is best treated as hearsay. Declines in mink abundance can be attributed to a variety of factors including: natural population fluctuations; changes in routes through which trappers marketed fur, i.e. not marketing fur through Mr. Johnson; changes in effort expended to trap mink; and changes in fur prices which may affect the level of trapping effort. Also, contaminant levels in Great Lakes salmonids have dropped considerably since the "first of the big coho runs" (see **Water Quality**). Could mink numbers in this portion of the river have rebounded and trapping effort not yet returned?

Comment: "Harding et al. (1999) found high rates of developmental abnormalities in the reproductive, digestive, and renal systems of mink from a wild British Columbia population exposed to low levels of PCBs. They also found a significant negative correlation between the size of the penis bone (baculum) in males at PCB concentrations in the liver in the range of 0.02 to 0.18 ug/g wet weight. In the same paper, the authors found that the size of otter male reproductive organs were significantly smaller in PCB contamination zones on the lower Columbia River in Oregon and in British Columbia when compared with an uncontaminated control area. Leonards et al. (1998) report that otter may be at least as sensitive to PCBs as are mink."

> Response: These are interesting observations, but we are unclear as to how they relate to mink and river otter population health or to specific issues on the Au Sable River. Again, we would like to see lower PCB levels in the Great Lakes, but if population-level concerns do not exist for fish-eating species, we see no reason to object to rehabilitation of the Au Sable River through fish passage or dam removal.

Comment: Paragraph 6, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "The second paragraph on page 81 is apparently an attack on the use of the accepted laboratory practice of using laboratory surrogates to predict toxicological outcomes in target species that, because of their rarity or difficulty in handling in a field situation, cannot be readily worked with in the field. We find the quantum jump all the way from ranch mink to wild mink to be less of a stretch than, say, fathead minnow to any other fish species, or rats to humans. This is simply the casting of aspersions at toxicology without any apparent basis. The Assessment would be improved if this section were removed."

> Response: We disagree with the suggestion. We are simply pointing out assumptions and methods used in hazard assessment studies and showing that study predictions may not always apply to real world situations.

Comment: Paragraph 6, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "Regardless of the uncertainties discussed by Johnson et al. (1996) with regard to trophic transfer of contaminants, the direct transfer of contaminants to fish and wildlife via ingestion of the contaminated fish themselves and their eggs is not disputable, nor is the potential for biomagnification during this direct transfer. Regardless of whether or not the entire upstream ecosystem becomes contaminated or not, and this is still open to conjecture, there is no doubt that the ingestion of these contaminated fish and their eggs by fish, wildlife, and humans can and does lead to the bioaccumulation and bioconcentration of contaminants at concentrations that have been demonstrated to be deleterious to these organisms and their populations."

> Response: Johnson et al. (1996) questioned the extent that biomagnification occurs because his field data did not show biomagnification to the extent that laboratory studies had predicted. Because these relations are not always as clear as one would expect from traditional biomagnification studies, the extent of bioaccumulation and bioconcentration of contaminants resulting from upstream passage of Great Lakes fishes may be very difficult to predict. Therefore, any such predictions should be closely scrutinized.

Comment: Paragraph 7, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "Finally, we take issue with your statement that potential increases in contaminant loads of animals feeding on the eggs and carcasses of Great Lakes fish represents a trade-off against the growth of individuals and the productivity of populations (third paragraph, page 81). The contaminant concentrations are simply too high, and must fall by at least an order of magnitude before anything like a trade-off should even be considered."

Response: We would also like to see lower contaminant levels in the Great Lakes, but waiting for further reductions in PCB levels may take many decades. Present observations suggest that providing upstream passage of Great Lakes fishes may pose little risk to current fish and wildlife populations. Existing knowledge suggests that the trade-offs favor fish passage or dam removal. Upstream migrations of Great Lakes fishes on other Michigan rivers are not causing ecological problems, are often highly desired, and increase the ecological sustainability of river and Great Lakes fish communities. Bald eagles are reproducing along Great Lakes–influenced shorelines and rivers at "stable" or "healthy" levels, approaching that of inland eagles. Interior fish populations would not be jeopardized by Great Lakes fishes, and populations of many native fishes would benefit. Exotic fishes would be poorly suited to free-flowing, river habitats and would probably occur in low numbers, if at all; sea lamprey would still have to be blocked from upstream areas. Finally, providing fish passage within the Au Sable River system upstream of Foote Dam would cause none of the contaminant transfer risks that are of such great concern to Consumers Energy.

Comment: Paragraph 7, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "Can it really be said with a high amount of certainty that production would not decrease because of introduced contaminants, even with the corresponding increase in food? Can these risks be quantified?"

Response: Many studies on rivers with salmon runs, particularly those in western North America have shown that salmon runs increase fish growth, survival, and standing crops. Such studies show that nutrients from the ocean (in the form of salmon carcasses) are carried inland via migrating fishes and incorporated into riparian forests, mammals, birds, and other organisms. Large runs of Great Lakes salmonids in Michigan rivers undoubtedly also have similar effects on riparian organisms. For example, each fall for the past 30 years, many tons of nutrients from Lake Michigan are carried up the Little Manistee River in the form of salmon and steelhead (carcasses and gametes) and made available to riverine organisms. The effects of this on the ecosystem can be readily quantified by comparing similar systems with and without runs of Great Lakes fishes. Quantification of effects of a steelhead run on fish growth, survival, and standing crops is presently occurring through an ongoing MDNR Fisheries Division study (MDNR Fisheries Division Dingell-Johnson Study 654).

Comment: Paragraph 8, *Considerations Regarding Upstream Passage of Great Lakes Fishes*: "…it is suggested that electric barriers (at considerable cost) could be implemented, in the case of dam removal, to prevent the invasion of sea lampreys (*Petromyzon marinus*) into the Au Sable River. However, according to the Great Lakes Fishery Commission (1999) electrical barriers were not totally effective in preventing the ingress of lampreys, and additionally were found to kill some fish that ventured too close to the barrier. This exhibits the ineffectiveness of current electric barriers at excluding lampreys and demonstrates the dangers that they present to aquatic life other than lampreys. There is a new type of electric barrier being designed that is said to be more effective and safe to other species, however these are still experimental and therefore are not as yet a viable option (GLFC 1999)….Foote Dam is a crucial, effective barrier in regulating lamprey populations by preventing lamprey migration.."

Response: We agree that sea lamprey would have to be blocked from upstream areas, but suggest that a 39-foot high dam is not needed to accomplish the job. Electric barriers represent just one of many possible options for blocking sea lampreys. We would insist that the best available technology be used to block sea lamprey migrations.

Comment: Dam removal or fish passage structures could lead to introduction of sea lamprey into upstream reaches where "they could seriously affect native fish populations".

> Response: We would insist that the best available technology be used to block upstream migrations of sea lamprey in the river. In the event that a few sea lamprey happened to make it upstream, they would pose no serious threat to native fish populations, since they are not parasitic when in rivers, and only enter them to spawn.

Comment: "Foote Dam and other hydroelectric projects also prevent or help prevent a host of exotic and invasive species from invading interior habitats, including, but not limited to: zebra mussels, white perch, European ruffe, and the round goby. These and other exotics presently inhabit Lake Huron and some of its tributaries, and pose significant threats to the ecosystems they invade….The combined effects of exotic introductions could decimate native fish populations in the Au Sable River and quickly spread to the entire watershed, where they are likely to affect wildlife and human inhabitants as well."

> Response: Dam removal or passage of exotic fishes in to free-flowing reaches of the Au Sable River would probably have little ecological effect on native fish populations. These reaches are generally too cold in the summer, have current velocities that are too high, and are too unproductive to support dense populations of the exotics mentioned above. The existing impoundments may provide suitable habitat some of these species, but water temperature conditions and low levels of productivity may limit the extent to which populations reach pest levels. Without the ponds, zebra mussels would be absent or at extremely low levels in the river. The statement that Foote Dam prevents zebra mussels from moving upstream is incorrect, because the ponds provide suitable habitat that allows upstream expansion of the zebra mussel's range.

Comment: Regarding potential effects of introducing exotic species into the river by fish passage or dam removal: White perch "would likely have a significant negative impact on the Au Sable River's population of native fishes, such as walleye and perch".

> Response: Evidence from where these species presently co-occur in the river system suggests otherwise. For example, Van Etten Lake, which is presently accessible to Lake Huron fishes and has white perch, has consistently provided a tremendous walleye and yellow perch fishery.

Comment: Regarding potential effects of introducing exotic species into the river by fish passage or dam removal: It is "likely that the round goby would negatively affect or even extirpate populations of the threatened channel darter". "Populations of native fishes especially emerald shiner, yellow perch, and trout perch have experienced significant declines since the invasion of the ruffe." The European ruffe poses a "clear and present danger to fisheries of the Au Sable River".

> Response: Round goby and European ruffe presently do not occur in portions of the Au Sable River connected to Lake Huron. Channel darters presently occur in the Pine River, which is accessible to Great Lakes fishes, and excellent channel darter habitat occurs beneath Cooke and Foote ponds. The main negative effect of round gobies in Michigan has been seen on mottled sculpin. Literature citations mentioned regarding the European ruffe indicated that associations between ruffe and abundance trends of the species mentioned in the comment are "not clear". The free-flowing portions of Au Sable River are probably too fast and cold for development of

any significant populations of round gobies or European ruffe (D. Jude, University of Michigan, personal communication).

Comment: "Given the extremely high probability of invasion of the Au Sable River by exotic species, Section 2(3) of the order [Executive Order 13112 signed by President Clinton] applies. This prohibits federal agencies from taking actions that would promote the introduction or spread of invasive species in the absence of overriding ecological or otherwise significant benefits that would outweigh the potential harm caused by the introduction of exotics."

Response: Given all that has been discussed in this document, we think that fish passage or dam removal on the Au Sable River presents a case where "overriding ecological or otherwise significant benefits would outweigh the potential harm caused by the introduction of exotics."

Comment: "The authors are to be commended for identifying and addressing fish passage issues."

Response: Comment noted.

Comment: "Also, there is more to the social issues than just conflicts between riparian residents and anglers. …As the land management agency with the majority of ownership along the mainstem Au Sable River, the U.S. Forest Service is concerned about the effects of increased angling use associated with runs of Lake Huron fishes such as salmon and steelhead into areas which currently do not have these fisheries. Additional factors that need to be taken into account include public access facilities (parking areas, sanitary facilities, boat launches, etc.) and the cost to manage such facilities. …These costs (of additional management) need to be factored into any analysis that includes the 'benefits' of fish passage."

Response: As the land management agency, the U.S. Forest Service can control how much access to the river they want. If desired, they can maintain the status quo, increase, or decrease the level of access to the river. In addition, the U.S. Forest Service now charges access site user fees which defray costs associated with access. Consequently, these "additional management" costs might already be factored in.

Comment: "While it is true that public sentiment is against the passage of potamodromous fish above Mio Dam, it still should be discussed as an option since passage is being considered as an option at all other mainstem dams."

Response: Passage of potamodromous fish above Mio Dam could be discussed as an option in the future, but we presently do not think it is an option for reasons stated in the paragraph 10, *Considerations Regarding Upstream Passage of Great Lakes Fishes*.

Comment: "All anadromous fish passage from Lake Huron should be stopped at Foote Dam. The social and biological passage of potamodromous fish species should be carefully reviewed. Salmon are not native to the Great Lakes and the chemical contamination they inflict upon co-inhabiting upstream animals is a major cause for concern. …Sadly, big fish attract bad people and in many cases bring out the worst in otherwise good people…littering, trespass, bank erosion, snagging, drunken behavior, and physical violence are standard behavior for many who 'fish' for salmon. …If we allow the Pacific salmon to reach Mio and Grayling there will be horrendous destruction of stream and riparian habitat…. The only way the river could survive such an onslaught would be with extremely restrictive regulations and thorough, vigorous law enforcement. …Let us remove the dams from the top down starting with Mio."

> Response: We disagree. This issue has been carefully reviewed. Available biological data suggests that there are tremendous benefits to passing Great Lakes fishes to upstream reaches and that little if any damage would be inflicted on river organisms now inhabiting upstream reaches. Passage of Great Lakes fishes is not being considered for the river upstream of Mio Dam for reasons discussed in the text. Salmon are as "native" to the Au Sable River as brook trout and brown trout. We understand the social ramifications associated with upstream passage of salmon. We agree that heavy use of certain areas of the river for fishing does lead to some of the problems mentioned, but do not think that this amounts to horrendous destruction of stream and riparian habitat. We understand that if Great Lakes fishes are allowed upstream, certain actions will be needed, including defining appropriate levels of access to the river, determining appropriate fishing regulations for affected reaches, assessing law enforcement needs, and determining numbers and species of fish to be passed upstream. Public comment will be sought throughout this process.

Comment: Paragraph 12, *Considerations Regarding Upstream Passage of Great Lakes Fishes:* "Focus should be on restoring self-sustaining potamodromous fish from Lake Huron, not just self-sustaining salmonids. While many introduced salmonids have become 'naturalized' stocks, acting as the ecological equivalents of native species which are no longer present, there are other potamodromous species which could be restored."

> Response: We agree and this was stated in the first sentence of paragraph 12, *Considerations Regarding Upstream Passage of Great Lakes Fishes.* Restoring self-sustaining salmonid stocks was specifically mentioned because stocking is needed to support their populations.

Recreational Use

Comment: "Recreational use on the Au Sable River impoundments including camping, day use, boating, and day use (visitor centers, scenic waysides, etc.) is not accounted for."

> Response: This information (and comments regarding its quality) have been incorporated into the text (see **Recreational Use**). We agree that more and better information on recreational use is needed throughout the river system.

Comment: A "complete discussion on commercial canoe usage and options to correct this carnage" is needed. Discussion is needed on watercraft controls and should addresses issues including rafting of watercraft, glass beverage containers, jet ski use, and no wake speed restrictions. "With over $600,000 having been spent by the Au Sable Watershed Restoration Committee in the past six years, 85% of erosion sites that received treatment can be attributed to commercial canoe activities. …The river is too valuable to the state, the nation, and the world to relegate any measure of its protection to local government or to allow its value to be influenced solely by economic factors. …Soon enough, with local control, there would be water slide amusement parks and jet ski races to attract more dollars to the community."

Response: We agree that increased commercial watercraft use on the river is undesirable. Management options were added which emphasize the need for protecting the river from excessive commercial watercraft use.

Comment: "While supporting voluntary efforts to minimize conflicts among user groups, it simply isn't enough. Since the enactment of the Natural Rivers Plan, commercial watercraft numbers have increased throughout the system. …Any possible regulations to control this carnage to our trout streams should include the following: 1) reductions in numbers to 1987 levels or below…2) time restrictions…3) use tax per trip to fund documented erosion damage caused by commercial canoe activities….4) a no-wake designation."

Response: We support any additional efforts to minimize conflicts among river users and agree that all options should be explored. This is reflected in the **Management Options** section.

Comment: Tables 28 and 29 should be re-labeled as Tables 27 and 28.

Response: This correction has been made.

Comment: "The canoe livery table (Table 28) only reflects data from liveries that serve the Natural River designated portions of the river, i.e. from the headwaters to Loud Dam. There are other liveries in the lower river area that are not reflected in this table. …the Natural River Act does not at this point limit the number of canoes that can be used on the river. The Au Sable River Natural River Plan has language regarding limiting commercial watercraft, but we don't at this point have a way to implement it. It is a very gray area of enforcement…."

Response: Changes have been made to pertinent portions of the table and text. Our support for limiting commercial watercraft use on the river is shown in the **Recreational Use** and **Management Options** sections.

Comment: "The correct mileage for [State Natural River] designated tributaries is 251, not 216."

Response: The correction has been made.

Management Options

Comment: "The options portrayed are presumed to be feasible and designed to improve the fisheries resources of the Au Sable River system, but may have different effects depending on when and where they are implemented. …it is very important for the DNR to convey the specific effects of each option to the extent possible, to the public…. These effects should include benefits, consequences, trade-offs, and relationships to other options."

Response: The Management Options presented represent a variety of options that would benefit the river system and deserve exploration. Options presented are not necessarily DNR options and may be pursued by any interested party. The methodologies, locations, benefits, consequences, trade-offs, relationships to other options, etc. should be discussed as each specific option is explored.

Comment: Agreement on several of the management options presented was reached in the Settlement Agreement.

> Response: This was mentioned in **Special Jurisdictions** and the Settlement Agreement is **Appendix 1**.

Comment: We object to removal of the power dams for the following reasons: 1) recreational opportunities would be lost; 2) economic loss/devastation for the surrounding areas; 3) wetlands for wildfowl would be lost; 4) elimination of warm-water fisheries in impoundments.

> Response: The Consumers Energy projects are licensed to operate until 2034. However, if dams were removed, several major changes would occur. The physical character of the river and types of recreation it supports would change; high-gradient rapids would replace pond wetlands (though wetlands may be created at the river mouth), coldwater fishing would replace warmwater fishing; canoeing would replace boating, etc. We question the extent to which economic devastation would occur, especially given the popularity and economic value of recreational opportunities on free-flowing rivers.

Comment: "Expand option regarding livestock grazing beyond the Pine River to also include the entire watershed."

> Response: The option was not expanded because this is the only area where there is a significant amount of livestock grazing.

Comment: "The use of rotenone to survey fish populations below Wakeley Bridge should not be an option."

> Response: Use of rotenone has been removed as one of the survey methods.

Comment: Include mussels and aquatic plants in the aquatic survey option.

> Response: Mussels are aquatic invertebrates. Aquatic plants and pest species were included in the option.

Comment: Based on the Au Sable River Assessment "grant applicants would be limited to soil erosion control, large woody debris projects, and dam removal".

> Response: We disagree. Grant applicants can apply for funds to accomplish *many* management options, in addition to those listed in the comment (see **Management Options**).

Comment: "Before this [dam removal] plan is activated please have public hearings and publish what concerns and benefits would take place."

> Response: All Consumers Energy projects are licensed to operate until 2034, so there is no near-term plan for removal of these dams. If Consumers Energy decided to remove one or more of these dams before 2034, there would surely be opportunities for public comment.

Comment: Recreational use surveys should "include the value of camping and day use (Visitor Centers, scenic attractions) as part of recreation use along river and its ponds in economic analysis".

Response: We agree that this information would be helpful in developing an overall recreational use survey for the watershed.

Comment: Economic valuation studies should "include assessment of the value of the environmental quality of life as well as the economic value".

Response: We agree that this information would be helpful in assessing the overall contribution of the Au Sable River to local communities.

Comment: "The Au Sable River Watershed Restoration Committee has already been in existence for a number of years and could aid in the formation and/or become the foundation of an Au Sable River Watershed Council."

Response: Comment noted.

GLOSSARY

base flow - groundwater discharge to the river

benthic – associated with the bottom of a stream or lake

catchment – the area of the earth's surface that drains to a particular location on a stream

cfs - cubic feet per second; a unit commonly used to express stream discharge

coniferous - cone-bearing, typically evergreen, trees

deciduous - vegetation that sheds its foliage annually

electrofishing - the process of putting an electric current, either AC or DC, through water for the purpose of stunning and capturing fish

entrain - to pass through the turbines of a hydroelectric dam

exceedence flow - a discharge amount that is exceeded by the stream for a given percentage of time. For example, for 90% of the year the stream's discharge is greater than its 90% exceedence flow value. Consequently, the 90% exceedence flow represents a stream's summer low (drought) flow.

exotic species - successfully reproducing organisms transported by human actions into regions where they did not previously exist

extirpation - to make extinct, eliminate completely

fauna - the animals of a specific region or time

FERC - Federal Energy Regulatory Commission

fixed-crest - a dam that is fixed at an elevation and has no ability to change from that elevation

flushing rate – the amount of time it takes for the total volume of water in an impoundment to be replaced by incoming streamflow; also referred to as retention time.

glacial-fluvial valley – a river valley formed by glacial melt waters cutting through deposits left by a glacier.

hydrology - the study of water

impoundment - water of a river system that has been held up by a dam, creating an artificial lake

instream cover - large woody debris (e.g. trees, logs, logjams) in the channel, overhanging banks, boulders, and macrophytes.

invertebrates - animals without a backbone

large woody debris – trees, logs, and logjams that are in a stream

lentic - non-flowing water; for example lentic fishes are in a non-flowing water or lake environment

lotic - flowing water; for example lotic habitats are habitats present in a flowing water environment

lower mainstem - the mainstem Au Sable River from Mio to Lake Huron

MDEQ - Michigan Department of Environmental Quality

MDNR - Michigan Department of Natural Resources

macrophytes - rooted aquatic plants with stems and leaves below the surface of the water (occasional exceptions have a few small floating or aerial leaves)

mitigation – action required to be taken to compensate for adverse effects of an activity

moraine - a mass of rocks, gravel, sand, clay, etc. carried and deposited directly by a glacier

naturalized - animals or plants previously introduced into a region that have become permanently established, as if native.

outwash - glacial deposits that have been sorted by flowing water; outwash deposits typically consist of sand, gravel, and larger substrates, with the finer-textured silts and clays having been washed away

pan evaporation - a measurement of the amount or rate of evaporation in a watershed

peaking - operational mode for a hydroelectric project that maximizes economic return by operating at maximum possible capacity during peak demand periods (generally 8 a.m. to 8 p.m.) and reducing or ceasing operations and discharge during non-peak periods; in other words, streamflows alternate between flood and drought on a daily basis

permeability - the ability of a substance to allow the passage of fluids. Sands and gravels have high permeability for water, because it readily moves through them.

potamodromous - fishes that migrate from one freshwater habitat to another over the course of their lives (in this report it refers to fish that migrate into the Au Sable River from Lake Huron)

retention time - the amount of time it takes for the total volume of water in an impoundment to be replaced by incoming streamflow. Also referred to as the reservoir's flushing rate.

riparian - adjacent to, or living on, the bank of a river

riverine - a reach or portion of a river that is free-flowing and not impounded by dams

rollway - high banks along the river upon which logs were stockpiled and rolled down to the water

run habitat - fast non-turbulent water

run-of-river - instantaneous inflow of water equals instantaneous outflow of water; on impounded systems, this flow regime mimics the natural flow regime of a river

seral - transitional stages of plant communities that occur over time

species richness - the number of different species collected at a site

standing crop - the abundance of organisms at a site, expressed in terms of number or biomass per unit area

surficial - referring to something on or at the surface

thalweg - the portion of a stream channel containing the majority of the river's flow.

thermocline - a layer of water between the warmer surface zone and the colder deep-water zone in a thermally stratified body of water (such as a lake), in which the temperature decreases rapidly with depth

till - unstratified, unsorted glacial deposits of clay, sand, boulders, and gravel

turbidity - water that has large amounts of suspended particles in the water column

upper mainstem - the mainstem Au Sable River upstream of Mio

USDA - Unites States Department of Agriculture

USFS - United States Forest Service

USGS - United States Geological Survey

veligers - larval stages of mussels that freely drift with water currents

wadable - a stream that is shallow enough to be traversed by someone wearing chest waders

watershed - an area of the earth's surface that drains toward a receiving body of water (such as a stream or lake) at a lower elevation

young-of-year - the offspring of fish that hatched this calendar year

REFERENCES

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. School of Natural Resources. University of Michigan, Ann Arbor, Michigan.

Alexander, G.R. 1976. Diet of vertebrate predators on trout waters in north central Lower Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1839, Ann Arbor, Michigan.

Alexander, G.R. 1977. Consumption of small trout by large predatory brown trout in the North Branch of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1855, Ann Arbor, Michigan.

Alexander, G.R. 1985. Comparative growth and survival potential of brown trout from four wild stocks and one domestic stock. Michigan Department of Natural Resources, Fisheries Division, Research Report 1929, Ann Arbor, Michigan.

Alexander, G.R., W.J. Buc, and G.T. Schnicke. 1979. Trends in angling and trout populations in the Main Au Sable and North Branch Au Sable Rivers from 1959-1976. Michigan Department of Natural Resources, Fisheries Division, Research Report 1865, Ann Arbor, Michigan.

Alexander, G.R., J.L. Fenske, and D.W. Smith. 1995. A fisheries management guide to stream protection and restoration. Michigan Department of Natural Resources, Fisheries Division, Special Report 15, Ann Arbor, Michigan.

Alexander, G.R, and H. Gowing. 1976. Relationships between diet and growth in rainbow trout (*Salmo gairdneri)*, brook trout *(Salvelinus fontinalis)*, and brown trout *(Salmo trutta)*. Michigan Department of Natural Resources, Fisheries Division, Research Report 1841, Ann Arbor, Michigan.

Alexander, G.R., and E.A. Hansen. 1983. Effects of sand bedload sediment on a brook trout population. Michigan Department of Natural Resources, Fisheries Division, Research Report 1906, Ann Arbor, Michigan.

Alexander, G.R., and E.A. Hansen. 1986. Sand bed load in a brook trout stream. North American Journal of Fisheries Management 6:9-23.

Alexander, G.R., and A.J. Nuhfer. 1993. Comparative catchability, growth, and survival of two wild stocks of brown trout. Michigan Department of Natural Resources, Fisheries Division, Research Report 1997, Ann Arbor, Michigan.

Alexander, G.R, and J.R. Ryckman. 1976. Trout production and catch under normal and special angling regulations in the North Branch of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1840, Ann Arbor, Michigan.

Alexander, G.R., and D.S. Shetter. 1962. Trout populations and predator studies, North Branch Au Sable, 1960-62. Michigan Department of Natural Resources, Fisheries Division, Research Report 1652, Ann Arbor, Michigan.

Alexander, G.R., and D.S. Shetter. 1967. Fishing and boating on portions of the Au Sable River in Michigan, 1960-63. Transactions of the American Fisheries Society 96(3):257-267.

Anonymous. 1982. Monetary values of freshwater fish and fish-kill counting guidelines. American Fisheries Society, Special Publication Number 13, Bethesda, Maryland.

Anonymous. 1987. Au Sable river natural river plan- Alcona, Crawford, Iosco, Montmorency, Oscoda, Otsego, and Roscommon counties. Michigan Department of Natural Resources, Land and Water Management Division, Lansing, Michigan.

Anonymous. 1993. A guide to public rights on Michigan waters. Michigan Department of Natural Resources, Law Enforcement Division, Report Number 9, Lansing, Michigan.

Anonymous. 1994. Water quality management practices on forest land. Michigan Department of Natural Resources, Forest Management Division, Lansing, Michigan.

Anonymous. 1995. Non-indigenous aquatic nuisance species state management plan–a strategy to confront their spread in Michigan. Michigan Department of Natural Resources, Office of the Great Lakes, Lansing, Michigan.

Anonymous. 1996. Mercury pollution prevention in Michigan. Michigan Department of Environmental Quality, Office of the Great Lakes, Lansing, Michigan.

Auer, N.A. 1995. Life history strategies of lake sturgeon, *Acipenser fulvescens*, in the Sturgeon River-Southern Lake Superior Ecosystem. Doctoral dissertation. Michigan Technological University, Houghton, Michigan.

Auer, N.A. 1996. Response of spawning lake sturgeons to change in hydroelectric facility operations. Transactions of the American Fisheries Society 125:66-77.

Bailey, R.M., and G.R. Smith. 1981. Origin and geography of the fish fauna of the Laurentian Great Lakes basin. Canadian Journal of Fisheries and Aquatic Sciences. 38:1539-1561.

Bain, M.B, J.T. Finn, and H.E. Booke. 1988. Streamflow regulation and community structure. Ecology 69(2):382-392.

Balon, E.K. 1975. Reproductive guilds of fishes: a proposal and definition. Journal of the Fisheries Research Board of Canada 32:821-864.

Beard, T.D., Jr., S.W. Hewett, Q. Yang, R.M. King, and S.J. Gilbert. 1997. Prediction of angler catch rates based on walleye population density. North American Journal of Fisheries Management 17:621-627.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press. Madison, Wisconsin.

Benjamin, B., and D.W. Smith. 1998. Great Lakes better backroads guidebook–clean water by design. Huron Pines Resource Conservation and Development Area Council, Inc. Grayling, Michigan.

Berry, T. 1992. Land use and stream discharge in Michigan's cold water streams. Master's thesis. University of Michigan, Ann Arbor, Michigan.

Bilby, R.E., B.R. Fransen, P.A. Bisson, and J.K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington. Canadian Journal of Fisheries and Aquatic Sciences 55:1909-1918.

Blumer, S.P., T.E. Behrendt, W.W. Larson, R.J. Minnerick, R.L. LeuVoy, and C.R. Whited. 1994. Water resources data–Michigan USGS, water year 1993.. United States Geological Survey, Geological Survey, Water Resources Division, Report USGS-WDR-MI-93-1, Lansing, Michigan.

Blumer, S.P., T.E. Behrendt, J.M. Ellis, R.J. Minnerick, R.L. LeuVoy, and C.R. Whited. 1998. Water resources data–Michigan USGS, water year 1997. United States Department of the Interior, Geological Survey, Water Resources Division, Report USGS-WDR-MI-97-1, Lansing, Michigan.

Booth, D. B. 1991. Urbanization and the natural drainage system–impacts, solutions, and prognoses. The Northwest Environmental Journal 7:93-118.

Bovee, K.D., T.J. Newcomb, and T.G. Coon. 1994. Relations between habitat variability and population dynamics of bass in the Huron River, Michigan. United States Department of the Interior, National Biological Survey, Biological Report 21, Washington, DC.

Bowerman, W. W., IV, and J. P. Giesy, Jr. 1991. Ecology of bald eagles on the Au Sable, Manistee, and Muskegon rivers. *In* Application for license for major project–existing dam, Manistee River, Tippy Project, FERC Project #2580, Hodenpyl Project, FERC (Federal Energy Regulatory Commission) Project #2599. Prepared for Consumers Power Company, work project number 412E322, Jackson, Michigan.

Bowerman, W. W., J. P. Giesy, D. A. Best, and V. J. Kramer. 1995. A review of factors affecting productivity of bald eagles in the Great Lakes region: implications for recovery. Environmental Health Perspectives 103:51-59.

Bowerman, W.W., D.A. Best, T.G. Grubb, G.M. Zimmerman, and J.P. Giesy. 1998. Trends of contaminants and effects in bald eagles of the Great Lakes Basin. Environmental Monitoring and Assessment 53:197-212.

Brett, J.R. 1979. Environmental factors and growth. Pages 599-675 *in* W.S. Hoar, D.L. Randall, and J.R. Brett eds. Fish physiology volume VIII. Academic Press, New York.

Brewer, R., G.A. McPeek, and R.J. Adams, Jr. 1991. The atlas of breeding birds of Michigan. Michigan State University Press, East Lansing, Michigan.

Carl, L.M. 1982. Natural reproduction of coho salmon and chinook salmon in some Michigan streams. North American Journal of Fisheries Management 2(4):375-380.

Clapp, D.F. 1988. Movement, habitat use, and daily activity patterns of trophy brown trout in the South Branch of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1988, Ann Arbor, Michigan.

Clark, R.D., Jr. 1981. Analysis of "quality fishing" regulations through mathematical simulation of a brown trout fishery. Michigan Department of Natural Resources, Fisheries Division, Research Report 1895, Ann Arbor, Michigan.

Clark, R.D., Jr. 1982. Evaluation of special regulations on the trout fishery of the Au Sable River, Mainstream, Crawford County, Michigan. Pages 109-124 *in* Michigan Project F-35-R-8 Fisheries Division Dingell-Johnson Annual Reports, October 1, 1981 to September 30, 1982. Ann Arbor, Michigan.

Clark, R.D., Jr. 1984. Evaluation of catch-and-release regulations on the South Branch of the Au Sable River, Crawford County, Michigan. Pages 97-101 *in* Michigan Project F-35-R-9 Fisheries Division Dingell-Johnson Annual Reports, October 1, 1982 to March 31, 1984. Ann Arbor, Michigan.

Clark, R.D., Jr. 1987. Evaluation of catch-and-release regulations on the Mainstream of the Au Sable River, Crawford County, Michigan. Pages 75-78 *in* Fisheries Division Michigan Dingell-Johnson Annual Reports Projects F-35-R-12 and F-53-R-3, April 1, 1986 to March 31, 1987. Ann Arbor, Michigan.

Clark, R.D., and G.R. Alexander. 1984. Effects of a slotted size limit on the brown trout fishery of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1927, Ann Arbor, Michigan

Clark, R.D., Jr. and G.R. Alexander. 1985. Effects of a slotted size limit on a multi species trout fishery. Michigan Department of Natural Resources, Fisheries Division, Research Report 1926, Ann Arbor, Michigan.

Clark, R.D., and G.R. Alexander. 1992. Evaluation of catch-and release trout fishing regulations on the South Branch of the Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1987, Ann Arbor, Michigan.

Clark, R.D., Jr., G.R. Alexander, and H. Gowing. 1979. Mathematical description of trout stream fisheries. Michigan Department of Natural Resources, Fisheries Division, Research Report 1869, Ann Arbor, Michigan.

Comer, P.J., D.A. Albert, H.A. Wells, B.L. Hart, J.B. Raab, D.L. Price, D.M. Kashian, R.A. Corner and D.W. Schuen. 1995. Michigan's native landscape, as interpreted from the General Land Office surveys 1816-1856. Michigan Natural Features Inventory, Lansing, Michigan. Digital map.

Commonwealth Cultural Resources Group. 1991. Phase I archaeological survey of the Au Sable River hydroelectric projects (Mio, Alcona, Loud, Five Channels, Cooke, and Foote). Contract report R-0064. Prepared for Consumers Power Company, Jackson, Michigan.

Consumers Power Company. 1991. Fish passage devices, Consumers Power Company hydroelectric projects on the Au Sable, Manistee and Muskegon rivers. *In* Application for license for major project, Muskegon River, Croton Project, FERC project number 2468, Consumers Power Company, Projects, Engineering & Construction Department, Jackson, Michigan.

Consumers Power Company. 1994. Au Sable River Land Management Plan. Jackson, Michigan

Coon, T.C. 1987. Responses of benthic riffle fishes to variation in stream discharge and temperature. Pages 77-85 *in* W.J. Mathews and D.C. Heins, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman, Oklahoma.

Cooper, G.P.; D.S. Shetter; and D.W. Hyne. 1959. Results of studies on Michigan trout waters with special angling restrictions (type of lure, size limit, creel limit). 1949-59. Michigan Department of Conservation, Fisheries Division, Research Report 1577, Ann Arbor, Michigan.

Coopes, G.F, M. Quigley, J.S. Richards, N. Ringler, and G.E. Burgoyne, Jr. 1974. Au Sable River watershed project biological report (1971-1973). Michigan Department of Natural Resources, Ann Arbor, Michigan.

Cushman, R.M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5:330-339.

Day, L., and J. Donahue. The mighty Au Sable–famed river top factor in Michigan's development. Bay City Times, July 22, 1951. Michigan woods and waters section.

Day, R. 1997. Michigan Fish Contaminant Monitoring Program–1997 Annual Report. Michigan Department of Environmental Quality, Surface Water Quality Division, Report MI/DEQ/SWQ-97/125, Lansing, Michigan.

De Vault, D.S., R. Hesselberg, P.W. Rodgers, and T.J. Feist. 1996. Contaminant trends in lake trout and walleye from the Laurentian Great Lakes. Journal of Great Lakes Research 22(4):884-895.

Dewberry, T.C. 1992. Protecting the biodiversity of riverine and riparian ecosystems: the national river public land policy development project. Transactions of the 57th North American Wildlife and Natural Resources Conference. pp. 424-432.

Donaldson, J. 1983. The last of Louis Chevalier–pioneer narratives of the Lake Huron Shore. Published by James G. Donaldson, Oscoda-Au Sable Historical Archives, Oscoda, Michigan.

Dorr, J.A., Jr., and D.F. Eschman. 1970. Geology of Michigan. University of Michigan Press. Ann Arbor, Michigan

Ecological Research Services, Inc. 1991. Toxic contaminants in certain Great Lakes fish and wildlife and their relevance to hydro relicensing decisions on the Au Sable, Manistee, and Muskegon rivers, Michigan. *In* Application for license for major project–existing dam, Muskegon River, Croton project, FERC (Federal Energy Regulatory Commission) project #2468. Under contract to the Michigan Audubon Society, prepared for Consumers Power Company under work package 412E322, Jackson, Michigan.

Edwards, E.A., G. Gebhart, and O.E. Maughan. 1983. Habitat suitability index models: smallmouth bass. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.6), Washington, DC.

Edwards, E.A., D.A. Krieger, M. Bacteller, and O.E. Maughan. 1982. Habitat suitability index models: black crappie. United States Department of the Interior, Fish and Wildlife Service Biological Report 82 (10.6) Washington, DC.

Eichenlaub, V.L. 1990. The climatic atlas of Michigan. University of Notre Dame Press, Notre Dame, Indiana.

Elliott, J.M. 1994. Quantitative ecology and the brown trout. Oxford University Press, New York, New York.

Ewins, P.J. 1994. Aquatic birds in recovering ecosystems–management conflicts. Journal of Great Lakes Research 20:597-598.

Farrand, W.R. and D.L. Bell. 1982. Quaternary geology of Michigan. Lansing, Michigan: Michigan Department of Natural Resources, Geological Survey Division. 2 sheets. Scale 1:500,000.

Fasquelle, E.R. 1954. When Michigan was young. W.B. Eerdmans Publishing Co., Grand Rapids, Michigan.

FERC (Federal Energy Regulatory Commission) 1994. Final multiple project environmental assessment for new hydropower licenses–Au Sable River projects: Mio Project, FERC No. 2448-011; Alcona Project, FERC No. 2447-008; Loud Project, FERC No. 2449-007; Five Channels Project, FERC No. 2453-003; Cooke Project, FERC No. 2450-005; Foote Project, FERC No. 2436-007. April 29, 1994 report prepared by FERC in cooperation with United States Department of Agriculture, Forest Service, Huron-Manistee National Forests, Michigan.

Giesy, J.P., D.A. Verbrugge, R.A. Othout, W.W. Bowerman, M.A. Mora, P.D. Jones, J.L. Newsted, C. Vandervoort, S.N. Heaton, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, G.A. Dawson, T.J. Kubiak, A. Best, and D.E. Tillitt. 1994a. Contaminants in fishes from Great Lakes-influenced sections and above dams of three Michigan rivers. II. Implications for health of mink. Archives of Environmental Contamination and Toxicology 27:213-223.

Giesy, J.W., D.A. Verbrugge, R.A. Othout, W.W. Bowerman, M.A. Mora, P.D. Jones, J.L. Newsted, C. Vandervoort, S.N. Heaton, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, M. Ludwig, G.A. Dawson, T.J. Kubiak, D.A. Best, and D.E. Tillitt. 1994b. Contaminants in fishes from Great Lakes-influenced sections and above dams on three Michigan rivers. I. Concentrations of organochlorine insecticides, polychlorinated biphenyls, dioxin equivalents, and mercury. Archives of Environmental Contamination and Toxicology. 27:202-212.

Giesy, J.P., W.W. Bowerman, M.A. Mora, D.A. Verbrugge, R.A. Othoudt, J.L. Newsted, C.L. Summer, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, G.A. Dawson, T.J. Kubiak, D.A. Best , and D.E. Tillitt. 1995. Contaminants in fishes from Great Lakes-influenced sections and above dams of three Michigan rivers: III. Implications for health of bald eagles. Archives of Environmental Contamination and Toxicology 29:309-321.

Gigliotti, L.M. 1989. No-kill fishing regulations: an assessment of the social and recreational characteristics and behaviors of Michigan stream trout anglers with special consideration of anglers on selected sections of the Au Sable River. Doctoral dissertation, Michigan State University, East Lansing, Michigan.

Gislason, J.C. 1985. Aquatic insect abundance in a regulated stream under fluctuation and stable diel flow patterns. North American Journal of Fisheries Management 5:39-46.

Goodyear, C.S., T.A. Edsall, D.M. Ormsby Dempsey, G.D. Moss, and P.E. Polanski. 1982. Atlas of the spawning and nursery areas of Great Lakes fishes. Volume five: Lake Huron. FWS/OBS-82/52. United States Department of the Interior, Fish and Wildlife Service, Washington, DC.

Gowing, H., and G.R. Alexander. 1980. Population dynamics of trout in some streams of the Northern Lower Peninsula of Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1877, Ann Arbor, Michigan.

Hallock, C. 1873. Sea and river fishing. Forest and Stream 1(8):122.

Harding, J.H., and J.A. Holman. 1990. Michigan turtles and lizards. Michigan State University Cooperative Extension Service Bulletin E-2234. East Lansing, Michigan.

Harding, J.H., and J.A. Holman. 1992. Michigan frogs, toads, and salamanders. Michigan State University Cooperative Extension Service Bulletin E-2350. East Lansing, Michigan.

Harding, L.E., M.L. Harris, C.R. Stephen, and J.E. Elliott. 1999. Reproductive and morphological condition of wild mink (*Mustela vison*) and river otters (*Lutra canadensis*) in relation to chlorinated hydrocarbon contamination. Environmental Health Perspectives 107:141-147.

Hay-Chmielewski, E.M., P.W. Seelbach, G.E. Whelan, and D.B. Jester, Jr. 1995. Huron River assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 16. Ann Arbor, Michigan.

Hay-Chmielewski, E.M. and G.E. Whelan. 1997. Lake sturgeon rehabilitation strategy. Michigan Department of Natural Resources, Fisheries Division, Special Report 18. Ann Arbor, Michigan.

Heaton, S.N., S.J. Bursian, J.P. Giesy, D.E. Tillitt, J.A. Render, P.D. Jones, D.A. Verbrugge, T.J. Kubiak, and R.J. Aulerich. 1995a. Dietary exposure of mink to carp from Saginaw Bay, Michigan. 1. Effects on reproduction and survival, and the potential risks to wild mink populations. Archives of Environmental Contamination and Toxicology 28:334-343.

Heaton, S.N., S.J. Bursian, J.P. Giesy, D.E. Tillitt, J.A. Render, P.D. Jones, D.A. Verbrugge, T.J. Kubiak, and R.J. Aulerich. 1995b. Dietary exposure of mink to carp from Saginaw Bay, Michigan: 2. Hematology and liver pathology. Archives of Environmental Contamination and Toxicology 29:411-417.

Heede, B.H. 1980. Stream dynamics: an overview for land managers. United States Department of Agriculture, Forest Service General Technical Report RM-72, Fort Collins, Colorado.

Hibbert, A.R. 1969. Water yield changes after converting a forested catchment to grass. Water Resources Research 5(3):634-640.

Holman, J.A. 1995. Ancient life of the Great Lakes basin. University of Michigan Press. Ann Arbor, Michigan.

Holman, J.A., J.H. Harding, M.M. Hensley, and G.R. Dudderar. 1989. Michigan snakes. Michigan State University Cooperative Extension Service Bulletin E-2000. East Lansing, Michigan.

Hubbs, C.L., and K.F. Lagler. 1947. Fishes of the Great Lakes region. The University of Michigan Press, Ann Arbor, Michigan.

Hudson, J.P. 1993. Seasonal and daily movements of large brown trout in the mainstem Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1998, Ann Arbor, Michigan.

Huggler, T. 1981. Early history of the Au Sable River. Oscoda County News July 16, 1981; Centennial feature story: pages 14-15.

Hunt, J.W., and G.N. Huntington. 1998. A comprehensive environmental investigation of an active artillery range. Federal Facilities Environmental Journal, Summer 1998, pages 43-53.

Huron Pines Resource Conservation and Development Area Council, Inc. 1996. Au Sable River watershed: road/stream crossing inventory report–Volume Ia. Grayling, Michigan.

Huron Pines Resource Conservation and Development Area Council, Inc. 1997. Au Sable River watershed: road/stream crossing inventory report–Volume IIa. Grayling, Michigan.

Insight Marketing, Inc. 1993. Final study results: recreation use associated with Consumers Power hydroelectric projects on the Au Sable River. Prepared for Consumers Power Company, Jackson, Michigan.

Inskip, P.D. 1982. Habitat suitability index models: northern pike. United States Department of the Interior, Fish and Wildlife Service Biological Report 82 (10.17), Washington, DC.

Johnson, P., and C.M. Nelson. 1996. Estimate summer 1994 watercraft use on the Au Sable River from Mio access site to the upper end of Alcona Pond. Contract report prepared by Michigan State University for United States Department of Agriculture, Forest Service, Mio Ranger District. February 28, 1996.

Johnson, J.E., W.D. Heckathorn, Jr., and A.L. Thompson. 1996. Dispersal and persistence of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) in a contaminated aquatic ecosystem, Bayou Meto, Arkansas. Transactions of the American Fisheries Society 125:450-457.

Keller, E.A., and F.J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes 4:361-380.

Kinney, J. 1999. Au Sable River impoundments fisheries assessments. Michigan Department of Natural Resources and U.S. Forest Service, Huron-Manistee National Forests. Unpublished manuscript dated, December 1999.

Knighton, D. 1984. Fluvial forms and process. Edward Arnold Ltd., London, Great Britain.

Kotanchik, J.C. 1997. Large-scale distribution of river otters in Michigan's Lower Peninsula. Master's thesis. University of Michigan, Ann Arbor, Michigan.

Kurta, A. 1995. Mammals of the Great Lakes region. University of Michigan Press, Ann Arbor, Michigan.

Large, A.R.G., and G.E. Petts. 1994. Rehabilitation of river margins. Pages 401-418 *in* P.Calow and G.E. Petts editors. The rivers handbook: hydrological and ecological principles, Volume 2. Blackwell Scientific Publications, Oxford, England.

Latta, W.C. 1998. Status of some of the endangered, threatened, special-concern and rare fishes of Michigan in 1997. Contract report prepared for Michigan Department of Natural Resources, Wildlife Division, Natural Heritage Program, Lansing, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991a. Application for license for major project–existing dam, Au Sable River Mio Project, FERC (Federal Energy Regulatory Commission) project number 2448, exhibit E–environmental report. Prepared for Consumers Power Company, Jackson, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991b. Application for license for major project–existing dam, Au Sable River Alcona Project, FERC (Federal Energy Regulatory Commission) project number 2447, exhibit E–environmental report. Prepared for Consumers Power Company, Jackson, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991c. Application for license for major project–existing dam, Au Sable River Loud Project, FERC (Federal Energy Regulatory Commission) project number 2449, exhibit E–environmental report. Prepared for Consumers Power Company, Jackson, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991d. Application for license for major project–existing dam, Au Sable River Five Channels Project, FERC (Federal Energy Regulatory Commission) project number 2453, exhibit E–environmental report. Prepared for Consumers Power Company, Jackson, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991e. Application for license for major project–existing dam, Au Sable River Cooke Project, FERC (Federal Energy Regulatory Commission) project number 2450, exhibit E–environmental report. Prepared for Consumers Power Company, Jackson, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991f. Application for license for major project–existing dam, Au Sable River Foote Project, FERC (Federal Energy Regulatory Commission) project number 2436, exhibit E–environmental report. Prepared for Consumers Power Company, Jackson, Michigan.

Lawler, Matusky, and Skelly Engineers. 1991g. Fisheries and aquatic resources–Au Sable River. Contract report LMSE-91/047&383/042. Prepared for Consumers Power Company, Jackson, Michigan.

Leopold, L.B. 1968. Hydrology for urban land planning–a guidebook on the hydrologic effects of urban land use. United States Geological Survey Professional Paper 554, Washington, DC.

Leopold, L.B., and T. Maddock Jr. 1953. The hydraulic geometry of stream channels and some physiographic implications. United States Geological Survey Professional Paper 252, Washington, DC .

Leopold, L.B., and M.G. Wolman. 1957. River channel patterns: Braided, meandering and straight. United States Geological Survey Professional Paper 282b pp. 33-85, Washington, DC.

Loud, E.F. 1981. How power development came to Oscoda and Au Sable. Pages 113-119 *in* The History of Iosco County, Michigan. The Iosco County Historical Society. East Tawas, Michigan.

Ludwig, J.P., J.P. Giesy, C.L. Summer, W. Bowerman, R Aulerich, S. Bursian, H.J. Auman, P.D. Jones, L.L. Williams, D.E. Tillitt, and M. Gilbertson. 1993. A comparison of water quality criteria for the Great Lakes based on human and wildlife health. Journal of Great Lakes Research 19:789-807.

MacDonald, O. 1942. A history of Au Sable and Oscoda. Master's thesis. Wayne State University. Detroit, Michigan.

Magnuson, J.J., L.B. Crowder, and P.A. Medvick. 1979. Temperature as an ecological resource. American Zoologist 19:331-343.

Martell, M. 1992. Bald eagle winter management guidelines. The Raptor Center, University of Minnesota, St. Paul, Minnesota.

Maser, C., and J. Sedell. 1994. From the forest to the sea: the ecology of wood in streams, rivers, estuaries, and oceans. St. Lucie Press, Delray Beach, Florida.

Mather, F. 1874. The Michigan grayling and its habit. Forest and Stream. 2(11):164-165.

McKinley, H.C. The Au Sable River. Crawford County Avalanche, May 25, 1933.

McMahon, T.E. 1982. Habitat suitability index models: creek chub. United States Department of the Interior, Fish and Wildlife Service Biological Report 82 (10.4), Washington, DC.

McMahon, T.E., and P.C. Nelson. 1984. Habitat suitability index models: walleye. United States Department of the Interior, Fish and Wildlife Service Biological Report 82 (10.56), Washington, DC.

Meisner, J.D., J.L. Goodier, H.A. Regier, B.J. Shuter, and W.J. Christie. 1987. An assessment of the effects of climate warming on Great Lakes basin fishes. Journal of Great Lakes Research 13(3):340-352.

Merna, J. W. 1986. Contamination of stream fishes with chlorinated hydrocarbons from eggs of Great Lakes salmon. Transactions of the American Fisheries Society 115:69-74.

Merron, G.S. 1982. Growth rate of brown trout (*Salmo trutta*) in areas of the Au Sable River, Michigan, before and after domestic sewage diversion. Michigan Department of Natural Resources, Fisheries Division, Research Report 1900, Ann Arbor, Michigan.

Michigan Department of Community Health. 1998. Michigan Department of Community Health Fish Consumption Advisory [Online]. Available: http://www.mdch.state.mi.us/pha/fishadvi.htm [1998, October 12].

Michigan Department of Conservation. 1922. The biennial report of the Department of Conservation of the State of Michigan 1921-1922. Lansing, Michigan.

Michigan Department of Conservation. 1924. The biennial report of the Department of Conservation of the State of Michigan 1923-1924. Lansing, Michigan.

Michigan Department of Conservation. 1966. Water resources conditions and uses in the Au Sable River basin. Water Resources Commission, Lansing, Michigan.

Michigan Society of Planning Officials. 1995. Patterns on the land: our choices–our future. Final report of the MSPO Trend Future Project. Rochester, Michigan.

Miller, H.L. 1963. The old Au Sable. W.B. Eerdmans Publishing Co., Grand Rapids, Michigan.

Morse, D.F. 1994. Biological surveys of the North Branch Au Sable and Au Sable Rivers and selected tributaries–Otsego, Roscommon, Crawford, Oscoda and Alcona counties–June 21-22, 1984 and August 31-September 2, 1992. Michigan Department of Natural Resources Surface Water Quality Division, November 1994, MI/DNR/SWQ-93/034, Lansing, Michigan.

Moyle, P.B. and J.J. Cech. 1982. Fishes: an introduction to ichthyology. Prentice Hall. Englewood Cliffs, New Jersey.

Nelson, F.A. 1986. Effect of flow fluctuation on brown trout in the Beaverhead River, Montana. North American Journal of Fisheries Management 6:551-559.

Norris, L.D. 1878. The Michigan grayling: What must be done to prevent the annihilation of this excellent food and game fish. Third annual session, Transactions of the Michigan Sportsman Association, Battle Creek, Michigan.

Northrup, A.J. 1880. Camps and tramps in the Adirondacks, and grayling fishing in northern Michigan: A record of summer vacations in the wilderness. Baker, Pratt and Co., New York.

Nuhfer, A.J. 1988. A comparison of growth of brown trout from selected western rivers with growth of brown trout from Michigan rivers. Michigan Department of Natural Resources, Fisheries Division, Technical Report 88-6, Ann Arbor, Michigan.

Nuhfer, A.J. 1992. Evaluation of the reintroduction of the arctic grayling, into Michigan lakes and streams. Michigan Department of Natural Resources, Fisheries Division, Research Report 1985, Ann Arbor, Michigan.

Nuhfer, A.J., and G.R. Alexander. 1991. Growth, survival, and vulnerability to angling of three wild brook trout strains exposed to different levels of angler exploitation over time. Michigan Department of Natural Resources, Fisheries Division, Research Report 1973, Ann Arbor, Michigan.

Nuhfer, A.J., R.D. Clark Jr., and G.R. Alexander. 1994. Recruitment of brown trout in the South Branch of the Au Sable River, Michigan, in relation to stream flow and winter severity. Michigan Department of Natural Resources, Fisheries Division, Research Report 2006, Ann Arbor, Michigan.

Oatka. 1888. Grayling fishing on the Au Sable. American Angler 14(2).

O'Neal, R.P. 1997. Muskegon River watershed assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 19, Ann Arbor, Michigan.

Osborne, L.L. and M.J. Wiley. 1988. Empirical relationships between land use/cover and stream water quality in an agricultural watershed. Journal of Environmental Management 26:9-27.

Peterson, H.L. 1957. The river of sands. Unpublished manuscript dated October 1957. Crawford County Library. Grayling, Michigan.

Peterson, A., R. Reznick, S. Hedin, M. Hendges, and D. Dunlap. 1998. Guidebook of best management practices for Michigan watersheds. Michigan Department of Natural Resources, Surface Water Quality Division, Lansing, Michigan.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation. Jefferson City, Missouri.

Poff, N.L., and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46:1805-1818.

Poff, N.L. and J.D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrologic variability. Ecology 76(2):606-627.

Quid. 1877. Grayling fishing on the Sauble. Forest and Stream 9(5):88.

Rakoczy, G. P., and R. D. Rogers. 1987. Sportfishing catch and effort from the Michigan waters of Lake Michigan, Huron, and Erie, and their important tributary streams, April 1, 1986 - March 31, 1987 (Appendices). Michigan Department of Natural Resources, Fisheries Division, Technical Report 87-6b, Ann Arbor, Michigan.

Rakoczy, G. P., and R. D. Rogers. 1988. Sportfishing catch and effort from the Michigan waters of Lake Michigan, Huron, and Erie, and their important tributary streams, April 1, 1987 - March 31, 1988 (Appendices). Michigan Department of Natural Resources, Fisheries Division, Technical Report 88-9b, Ann Arbor, Michigan.

Rakoczy, G. P., and R. D. Rogers. 1990. Sportfishing catch and effort from the Michigan waters of Lake Michigan, Huron, and Erie, and their important tributary streams, April 1, 1988 - March 31, 1989 (Appendices). Michigan Department of Natural Resources, Fisheries Division, Technical Report 90-2b, Ann Arbor, Michigan.

Raleigh, R.F. 1982. Habitat suitability index models: brook trout. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.24), Washington, DC.

Raleigh, R.F., and P.C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: pink salmon. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.109), Washington, DC.

Raleigh, R.F., W. J. Miller and S.C. Nelson. 1986a. Habitat suitability index models and instream flow suitability curves: chinook salmon. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.122), Washington, DC.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986b. Habitat suitability index models and instream flow suitability curves: brown trout. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.124), Washington, DC.

Regal, G.E. 1992. Range of movement and daily activity of wild brown trout in the South Branch Au Sable River, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1988, Ann Arbor, Michigan.

Richards, J.S. 1976. Changes in fish species composition in the Au Sable River, Michigan from 1920's to 1972. Transactions of the American Fisheries Society 1:32-40.

Richards, R.P. 1990. Measures of flow variability and a new flow based classification of Great Lakes tributaries. Journal of Great Lakes Research 16(1):53-70.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada, 5^{th} edition. American Fisheries Society Special Publication 20, Bethesda, Maryland.

Rozich, T. 1998. Manistee River assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 21. Ann Arbor, Michigan.

Rutherford, E., S. Thorrold, A. Woldt, D. Swank, and N. Godby. 1997. Abundance, production, and harvest of salmonids in the Manistee, Muskegon, and Au Sable rivers. Michigan Department of Natural Resources, Fisheries Division, 1996-97 progress report for Project # 231663, Ann Arbor, Michigan.

Schlosser, I.J. 1991. Stream fish ecology: A landscape perspective. BioScience 41(10):704-712.

Schneider, J.C., and J.H. Leach. 1979. Walleye stocks in the Great Lakes, 1800-1975: fluctuations and possible causes. Great Lakes Fishery Commission Technical Report 31. Ann Arbor, Michigan.

Schultz, D.L. 1986. Report of the survey to assess the current status of *Percina copelandi* and *Percina shumardi* in Michigan. September 6, 1986. University of Michigan, Museum of Zoology and Department of Biological Sciences, Ann Arbor, Michigan

Science Applications International Corporation. 1993. Revised Lake Michigan lakewide management plan for toxic pollutants. Produced for United States Environmental Protection Agency, Chicago, Illinois.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. Ottawa, Canada.

Scrudato, R. J., and W. H. McDowell. 1989. Upstream transport of mirex by migrating salmonids. Canadian Journal of Fisheries and Aquatic Science 46:1484-1488.

Seelbach, P.W. 1986. Population biology of steelhead in the Little Manistee River, Michigan. Doctoral dissertation. University of Michigan, Ann Arbor, Michigan.

Seelbach, P.W., M.J. Wiley, J.C. Kotanchik, and M.E. Baker. 1997. A landscape-based ecological classification system for river valley segments in Lower Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 2036, Ann Arbor, Michigan.

Shetter, D.S. 1967. Observations on movements of wild trout in two Michigan stream drainages. Michigan Department of Natural Resources, Fisheries Division, Research Report 1743, Ann Arbor, Michigan.

Shetter, D.S., and G.R. Alexander. 1964. Angling and trout populations on the North Branch of the Au Sable River, Crawford and Otsego counties, Michigan, under special and normal regulations, 1958-1963. Michigan Department of Natural Resources, Fisheries Division, Research Report 1701, Ann Arbor, Michigan.

Shetter, D.S., and G.R. Alexander. 1966. Progress report on brown trout removal from 4.2 miles of the North Branch of the Au Sable River, 1964 and 1965. Michigan Department of Natural Resources, Fisheries Division, Research Report 1721, Ann Arbor, Michigan.

Smith, S.H. 1972. Factors of ecologic succession in oligotrophic fish communities of the Laurentian Great Lakes. Journal of the Fisheries Board of Canada 29:717-730.

Sprunt, A. IV, W.B. Robertson, S. Postupalsky, R.J. Hensel, C.E. Knoder, and J.J. Ligas. 1973. Comparative productivities of six bald eagle populations. Transactions of the North American Wildlife Conference 38:96-106.

Stalmaster, M., and J. Gressamer. 1984. Ecological energetics and forage behavior of overwintering bald eagles. Ecological Monographs 54(4):407-428.

Starrett, W.C. 1951. Some factors affecting the abundance of minnows in the Des Moines River, Iowa. Ecology 32(1):13-27.

State Board of Fish Commissioners. 1909a. Seventeenth biennial report of the State Board of Fish Commissioners for fiscal years 1905 and 1906. Wynkoop Hallenbeck Crawford Company, State Printers, Lansing, Michigan.

State Board of Fish Commissioners. 1909b. Eighteenth biennial report of the State Board of Fish Commissioners for fiscal years 1907 and 1908. Wynkoop Hallenbeck Crawford Company, State Printers, Lansing, Michigan.

Stoll, B. 1951. The mighty Au Sable–power dams mark modern phase of river's history. Bay City Times, August 5, 1951. Michigan Woods and Waters section: page 32.

Strange, E.M., P.B. Moyle, and T.C. Foin. 1992. Interactions between stochastic and deterministic processes in stream fish community assembly. Environmental Biology of Fishes 36:1-15.

Strogen, J.W., Jr. 1979. A comparison of the diet and growth of trout from the upper Au Sable and upper Manistee rivers, Michigan. Michigan Department of Natural Resources, Fisheries Division, Research Report 1867, Ann Arbor, Michigan.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982a. Habitat suitability index models: bluegill. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.8), Washington, DC.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982b. Habitat suitability index models: largemouth bass. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.16), Washington, DC.

Thornton, N. 1987. Along the historic Riviere aux Sables. Printer's Devil Press, Tawas City, Michigan.

Thuemler, T.F. 1985. The lake sturgeon, *Acipenser fulvescens*, in the Menominee River, Wisconsin-Michigan. Pages 73-78 *in* F.P. Binkowski and S.I. Doroshov eds. North American sturgeons: biology and aquaculture potential. Dr. W. Junk Publishers, Dordrecht, Netherlands.

Toffaleti, C., and J.A. Bobrin. 1991. Nonpoint pollution in the Ann Arbor-Ypsilanti area: A preliminary control strategy for the Huron River Watershed. Washtenaw County Drain Commissioner, Ann Arbor, Michigan.

Trautman, M.B. 1942. Fish distribution and abundance correlated with stream gradient as a consideration in stocking programs. Pages 211-223 *in* Transactions of the Seventh North American Wildlife Conference, Washington, DC.

Trautman, M.B. 1981. The fishes of Ohio. Ohio State University Press, Columbus, Ohio.

Trial, J.G., J.G. Stanley, M. Batcheller, G. Gebhart, O.E. Maughan, P.C. Nelson, R.F. Raleigh, and J.W. Terrell. 1983. Habitat suitability index models: blacknose dace. United States Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.41), Washington, DC.

Twomey, K.A., K.L. Williamson, P.C. Nelson, and C. Armour. 1984. Habitat suitability index models and instream flow suitability curves: white sucker. United Stated Department of the Interior, Fish and Wildlife Service, Biological Report 82 (10.64), Washington, DC.

United States Department of Agriculture, Forest Service. 1986. Huron-Manistee National Forest, Land and Resource Management Plan. Cadillac, Michigan.

United States Department of the Interior, Fish and Wildlife Service, and United States Department of Commerce, Bureau of the Census. 1991. 1991 national survey of fishing, hunting, and wildlife-associated recreation. Washington, DC.

United States Environmental Protection Agency. 1997. Deposition of air pollutants to the Great Waters–2nd report to Congress. June 1997. Environmental Protection Agency report EPA-453/R-97-011, Washington, DC.

Urie, D.H. 1966a. Influence of forest cover on ground-water recharge, timing, and use. *In* International Forest Hydrology Symposium Proceedings p. 313-324. Pennsylvania State University, State College, Pennsylvania.

Urie, D.H. 1966b. Influence of forest cover on snowpack and ground-water recharge. Ground Water 4(1):5-9.

Urie, D.H. 1977. Groundwater differences on pine and hardwood forests of the Udell Experimental Forest in Michigan. USDA (United States Department of Agriculture) Forest Service Research Paper NC-145. North Central Forest Experimental Station, St. Paul, Minnesota.

USGS (United States Geological Survey). 1978. Water resources data for Michigan, water year 1977. Report USGS-WDR-MI-77-1. United States Department of the Interior, Geological Survey, Water Resources Division, Lansing, Michigan.

USGS (United States Geological Survey). 1998. 1990 water use data for 04070007–Au Sable [Online]. Available: http://water.usgs.gov/cgi-bin/wuhuc?huc=04070007 [1998, July 21].

Vincent, R.E. 1962. Biogeographical and ecological factors contributing to the decline of Arctic grayling, *Thymallus arcticus* Pallus, in Michigan and Montana. Doctoral dissertation. University of Michigan, Ann Arbor, Michigan.

Ward, J.V., and J.A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Pages 29-42 *in* T.D. Fontaine and S.M. Bartell editors. Dynamics of lotic ecosystems. Ann Arbor Science, Ann Arbor, Michigan.

Westerman, F.A. 1961. On the history of trout planting and fish management in Michigan. Pages 15-37 *in* Michigan fisheries centennial report 1873-1973. Michigan Department of Natural Resources, Fisheries Division, Management Report 6, Lansing, Michigan.

Whitney, G.G. 1986. Relation of Michigan's presettlement pine forests to substrate and disturbance history. Ecology 67(6):1548-1559.

Wiley, M.J., S.L. Kohler, and P.W. Seelbach. 1997. Reconciling landscape and local views of aquatic communities: lessons from Michigan trout streams. Freshwater Biology 37:133-148.

Wiley, M.J., and P.W. Seelbach. 1997. An introduction to rivers–the conceptual basis for the Michigan Rivers Inventory (MRI) project. Michigan Department of Natural Resources, Fisheries Division, Special Report 20, Ann Arbor, Michigan.

Wren, C. D. 1991. Cause-effect linkages between chemicals and populations of mink (*Mustela vison*) and otter (*Lutra canadensis*) in the Great Lakes basin. Journal of Toxicology and Environmental Health 33:549-585.

Zorn, T.G., and P.W. Seelbach. 1992. A historical perspective of the Clinton River watershed and its fish communities. Michigan Department of Natural Resources, Fisheries Division, Technical Report 92-10, Ann Arbor, Michigan.

Zorn, T.G., P.W. Seelbach, and M.J. Wiley. 1997. Patterns in the distributions of stream fishes in Michigan's Lower Peninsula. Michigan Department of Natural Resources, Fisheries Division, Research Report 2035, Ann Arbor, Michigan.

TABLES

Table 1.–Groundwater accrual to the Au Sable River and major tributaries as shown by downstream changes in base flow discharge. Data from Coopes et al. (1974).

Location	Miles above mouth	Discharge (cfs)	Increase in cfs per mile
Headwaters to Grayling			
Flows measured on February 8, 1973			
Kolke Creek	Mouth	18.8	–
Bradford Creek	Mouth	17.0	–
Frederic Co. Rd. 612	127.1	54.3	5.5
Batterson Rd.	125.2	60.5	3.3
Pollack Br.	118.1	73.8	1.9
Grayling (US-27)	114.2	86.0	3.1
Mainstream-Grayling to Mio			
Flows measured on July 20, 1972			
Grayling (US-27)	114.2	76.0	–
Old Wastewater Treatment Plant discharge	113.4	92.9	20.0
I-75 (East Branch Au Sable enters upstream)	112.7	141.4	1.4
Above Burtons Landing	109.2	163.5	0.6
Wa Wa Sum	106.2	213.6	16.7
Stephans Bridge	104.6	230.7	10.6
Wakeley Bridge	100.3	278.5	11.2
Beaver Bend	93.5	511.4	9.0
Mio (several major tribs. enter upstream)	73.0	862.0	1.3
East Branch			
Flows measured on February 1, 1973			
Co. Road 612	13.3	18	–
Below Jones Lake	12.6	22	5.7
Robinson Dam	10.8	35	7.2
Military Road	7.5	41	1.8
Wilcox Bridge	3.7	44	0.8
Hatchery	0.4	55	3.3
South Branch			
Flows measured on August 15, 1972			
Chase Bridge	14.3	91	–
Smith Bridge	4.6	136	4.6
Oxbow	1.9	178	15.6
Mouth	0.0	133	-23.7
North Branch			
Flows measured on June 11, 1971			
Old State Road	34.2	16	–
The Ford	28.1	78.7	1.9
Blackhole	21.3	125	5.2
Lovells Co. Rd. 612	16.0	161	6.8
Kelloggs Bridge	4.1	204	3.6

Table 2.–Groundwater accrual to the Au Sable River below Parmalee Bridge as shown by downstream changes in 90% exceedence flows for the 1997 water year. A disproportionate increase in the 90% exceedence flow, relative to that for drainage area, indicates an inflow of groundwater. Data from Blumer et al. (1998).

Location	Drainage area (mi^2)	90% exceedence flow (cfs)	Increase in drainage area(%)	Increase in 90% exceedence flow(%)
Parmalee Bridge	1108	658	–	–
Below Mio Dam	1361	804	18.6	18.2
McKinley Bridge	1513	966	10.0	16.8
Below Alcona Dam	1598	993	5.3	2.7
Below Foote Dam	1739	1170	8.1	15.1

Table 3.–Gradient of the mainstem, North, South, and East branches of the Au Sable River, and the West Branch of Big Creek-North. Data from Michigan Department of Natural Resources, Fisheries Division, unpublished data.

River mile	Distance (miles)	Gradient (ft/mi)	Comments
Au Sable River			
155.3	2.1	3.13	Confluence Kolke Ck. and Bradford Ck. to Frederic
153.2	1.4	7.18	Frederic
151.8	1.0	9.46	
150.8	4.5	2.22	Sand Hill Lake
146.3	2.0	1.49	From Contour 1500 to Salling Pond
144.3	2.0	6.63	Salling Impoundment (Elev. 1147)
142.3	2.2	3.37	From Salling Dam to Grayling Dam
140.1	0.5	9.73	Grayling Dam (Elev. 1126.7)
139.6	0.2	11.61	From Grayling Dam (Elev. 1121.8) to Contour 1120
139.4	4.3	2.31	I-75 Crossing
135.1	2.0	4.95	Forest HQ
133.1	1.2	8.39	Louis Cabin Landing
131.9	2.2	4.63	Wa-Wa-Sum
129.7	1.8	5.63	Stephans Bridge
127.9	0.9	11.24	Below Shoppenagon
127.0	1.4	7.39	Ginger Quill
125.6	1.2	8.09	Wakeley Bridge
124.4	1.3	7.99	
123.1	3.4	2.98	South Branch Au Sable River
119.7	2.3	4.26	Conners Flat
117.4	2.8	3.58	
114.6	4.1	2.45	Whitewater Creek
110.5	3.5	2.83	Parmalee
107.0	3.3	3.04	Whirlpool public access site
103.7	1.3	5.18	
102.4	3.4	2.06	Mio Pond
99.0	4.2	2.41	Mio Pond
94.8	1.5	6.88	Mio Pond
93.3	0.3	8.65	Mio Pond
93.0	1.1	3.42	From Mio Dam downstream
91.9	2.0	4.98	
89.9	2.2	4.59	Cauchy Creek
87.7	2.4	4.16	Comins public access site
85.3	1.9	5.29	
83.4	2.7	3.67	
80.7	3.6	2.80	McKinley public access site
77.1	2.7	3.64	
74.4	3.2	6.16	O'Brien Lake (Contour 860 to Contour 840)
71.2	1.7	6.90	Au Sable River Rd (Contour 840 to Alcona Pond 828)
69.5	2.6	2.69	Alcona Pond
66.9	1.0	10.53	Alcona Pond

Table 3.–Continued.

River mile	Distance (miles)	Gradient (ft/mi)	Comments
Au Sable River (continued)			
65.9	1.3	7.73	Alcona Pond
64.6	2.8	3.62	Alcona Pond
61.8	0.4	10.10	Alcona Pond
61.4	2.9	3.03	From Alcona Dam downstream
58.5	4.5	4.42	Hoppy Creek
54.0	2.1	4.74	
51.9	0.8	8.94	
51.1	3.2	2.20	Loud Pond
47.9	1.8	5.49	Loud Pond
46.1	1.5	6.73	Loud Pond
44.6	0.8	6.43	Loud Pond
43.8	1.4	11.40	Five Channels Pond
42.4	1.2	8.42	Five Channels Pond
41.2	1.0	12.31	Five Channels Pond
40.2	2.7	1.49	Cooke Pond
37.5	3.8	2.65	Cooke Pond
33.7	3.0	3.34	Cooke Pond
30.7	4.0	2.48	Cooke Pond
26.7	1.5	3.39	Cooke Pond
25.2	6.1	2.47	Foote Pond
19.1	4.3	2.35	Foote Pond
14.8	3.2	3.10	Foote Pond
11.6	1.4	1.43	Foote Pond
10.2	2.5	2.37	From Foote Dam downstream
7.7	7.7	1.29	From Oscoda to Lake Huron
0.0			Lake Huron
East Branch Au Sable River			
18.4	2.3	3.83	from Barnes Lake (elevation 1209 ft) to outlet of pond at Timber Lake outlet
16.1	0.6	4.85	To River Lake (elevation 1197 ft)
15.4	0.3	0.00	Across River Lake
15.1	3.0	2.35	Co Rd 612
12.1	1.8	5.66	
10.4	1.7	6.06	
8.7	2.5	4.03	
6.2	2.1	4.74	
4.1	1.1	9.37	
3.0	1.3	7.56	
1.7	1.3	7.47	Grayling Fish Hatchery
0.4	0.4	2.62	to Mainstem Au Sable River
0.0			Mainstem Au Sable River

Table 3.–Continued.

River mile	Distance (miles)	Gradient (ft/mi)	Comments
South Branch Au Sable River			
45.0	0.4	11.24	From dam below Mud Lake (1154 ft)
44.6	8.0	1.25	M76, Keno Rd, South Creek
36.6	9.9	1.01	Sherman Bridge, Hudson and Asum creeks
26.7	3.3	3.05	
23.4	4.0	2.49	Roscommon
19.4	5.3	1.88	Steckert Br, Chase Br
14.1	1.9	5.29	Douglas and Thayer creeks
12.2	3.4	2.96	Canoe Harbor Campground, Sauger Creek
8.8	1.6	6.08	Smith Br (M72)
7.2	2.0	5.01	
5.2	1.4	7.15	
3.8	1.5	6.68	To confluence with Mainstem Au Sable River
2.3	2.3	2.17	Mainstem Au Sable River
0.0			
North Branch Au Sable River			
36.7	1.4	6.99	Stream is intermittent for about 500' during this 10' drop
35.2	1.5	6.47	Goose Lk outlet enters
33.7	0.7	10.53	into Emerald Lk (elev 1243')
33.0	0.7	0.00	across Emerald and Bill Marie Lks, Range Line Dam
32.3	0.7	4.32	
31.6	1.2	8.18	Old State Rd 618, several small pools (ponds)
30.4	2.4	4.21	Chub Creek
28.0	1.8	5.55	
26.2	1.6	6.21	
24.6	0.8	12.19	Camp Grayling- North Boundary
23.8	1.3	7.48	Pigeon River State Forest
22.5	1.9	5.26	Holcomb Lodge
20.6	1.2	8.33	KP Twin Bridge Truck Trail
19.4	1.3	7.71	Lovells, Co Rd 612
18.1	1.1	8.93	
17.0	1.1	8.90	
15.8	1.3	7.89	
14.6	1.3	7.51	High Bank Lodge
13.2	1.0	10.38	Au Sable Trout and Gun Club
12.3	0.7	15.17	
11.6	1.7	6.00	
10.0	1.7	5.82	
8.2	0.6	16.40	Lovells Rd
7.6	0.8	12.28	
6.8	1.8	5.59	N. Down River Rd, Big Creek
5.0	1.3	7.54	
3.7	1.8	5.51	Carter Creek

Table 3.–Continued.

River mile	Distance (miles)	Gradient (ft/mi)	Comments
North Branch Au Sable River (continued)			
1.9	1.6	6.29	
0.3	0.3	1.72	to Mainstem Au Sable River
0.0			Mainstem Au Sable River
West Branch of Big Creek-North			
21.9	0.4	23.79	
21.5	1.2	8.46	Caulkins Lake outlet enters
20.3	2.5	3.93	7th Spectacle Lake outlet enters
17.7	0.7	15.11	
17.1	0.1	67.95	Graham Lake outlet enters
16.9	0.6	16.11	
16.3	0.8	12.54	
15.5	1.1	8.97	
14.4	0.8	12.64	Co Rd 612
13.6	1.7	5.96	
11.9	1.6	6.10	
10.3	2.4	4.09	
7.9	1.2	8.56	
6.7	2.8	3.62	
3.9	0.8	11.93	
3.1	0.5	20.20	
2.6	0.6	17.90	
2.0	0.9	10.78	E Br Big Creek enters, Blonde Dam Bridge
1.1	1.1	6.34	To confluence w/ N Br Au Sable River
0.0			North Branch Au Sable River

Table 4.–Analysis of historical channel data for the Au Sable River upstream of Mio Pond. Stream width and channel hydraulic diversity was calculated from United States Geological Survey transect measurements. Channel hydraulic diversity categories and values are: Poor: 0-1.5; Fair: 1.6-2.0; Good: 2.1-2.5; and Excellent: >2.5. Low-flow discharge measurements (Q) were measured or extrapolated from Coopes et al. (1974), and used to calculate expected widths. Status indicates whether site is outside of expected range; "W" is too wide and "N" is too narrow. Expected mean width, and upper and lower 95% widths were calculated using the following equations (Leopold and Maddock 1953; Leopold and Wolman 1957):

Lower 95% width = $10^{(0.662895 + (0.471522*\log_{10}(Q)))}$
Mean width = $10^{(0.741436 + (0.498473*\log_{10}(Q)))}$
Upper 95% width = $10^{(0.819976 + (0.525423*\log_{10}(Q)))}$

Location	Discharge (cfs)	Channel hydraulic diversity	Actual width (ft)	Expected widths (ft)			Status
				Mean	Lower 95%	Upper 95%	
Mainstem							
Pollack Bridge- 5 mi upstream of Grayling	74	1.75	34	47	35	63	N
Old Dam Road- 2 mi upstream of Grayling	80	2.02	41	49	36	66	
Canoe Camp- 4 mi downstream of Grayling	163	2.17	103	70	51	96	W
Burton's Landing- 7 mi downstream of Grayling	164	2.13	58	70	51	96	
Keystone- 7.5 mi downstream of Grayling	180	2.07	98	73	53	101	
WaWaSum- 8 mi downstream of Grayling	214	2.04	77	80	58	111	
Stephan Bridge- 10.5 mi downstream of Grayling	231	1.88	51	83	60	115	N
Wakeley Bridge- 14.5 mi downstream of Grayling	279	2.12	91	91	65	127	
East Branch							
CCC Bridge- below Jones Lake	22	1.72	19	26	20	34	N
Near I-75- below Alexander Creek	48	1.87	21	38	29	51	N
North Branch							
The Ford- 6.3 mi above Lovells	79	1.85	76	49	36	65	W
The Black Hole- 3.0 mi above Lovells	125	2.17	96	61	45	84	W
Lovells	161	1.93	41	69	51	95	N
Eamons- 2 mi below Lovells	168	1.72	115	71	52	98	W
South Branch							
Chase Bridge	91	2.11	63	52	39	71	
Castle- 4 mi below Chase Bridge	109	2.2	53	57	42	78	

Table 5.–Analysis of historical channel data for the Au Sable River from Mio Dam to Lake Huron. Stream discharge, channel width, and channel hydraulic diversity values were averaged from measurements at several transects, the number of which is shown under "n". Channel hydraulic diversity categories and values are: Poor: 0-1.5; Fair: 1.6-2.0; Good: 2.1-2.5; and Excellent: >2.5. Data from Consumers Energy. Status indicates whether site is outside of expected range; "W" is too wide and "N" is too narrow. Expected mean width, and upper and lower 95% widths were calculated using the following equations (Leopold and Maddock 1953; Leopold and Wolman 1957):

$$\text{Lower 95\% width} = 10^{(0.662895 + (0.471522 * \log_{10}(Q)))}$$
$$\text{Mean width} = 10^{(0.741436 + (0.498473 * \log_{10}(Q)))}$$
$$\text{Upper 95\% width} = 10^{(0.819976 + (0.525423 * \log_{10}(Q)))}$$

Location	Discharge (cfs)	Channel hydraulic diversity	Actual width (ft)	n	Expected widths (ft) Mean	Expected widths (ft) Lower 95%	Expected widths (ft) Upper 95%	Status
Mio Dam to Alcona Dam								
1.5-2.1 miles below Mio Dam	758	2.36	166	4	150	105	215	
4.5-4.9 miles below Mio Dam	823	2.23	184	4	157	109	225	
10.6-11 miles below Mio Dam near Glennie Creek	930	2.57	136	5	166	115	240	
1.5 miles below McKinley Bridge	1017	2.66	155	5	174	120	251	
Gabions Public Access Site	931	2.46	169	4	166	116	240	
Alcona Dam to Loud Impoundment								
0.4-0.6 miles below Alcona Dam	1535	2.64	168	6	214	146	312	
0.2 miles above Smith Creek	1582	2.67	153	9	217	148	317	
1.9 miles above South Branch River	1578	2.50	170	7	217	148	316	
7.3 miles below Alcona Dam	1632	2.53	139	6	220	151	322	N
Foote Dam to Lake Huron								
0.6 miles below Foote Dam	975	2.84	169	8	170	118	246	
1.9 miles below Foote Dam at Highbanks	1054	3.00	187	8	177	123	256	
6.3-6.6 miles below Foote Dam	1047	2.68	247	4	177	122	255	

Table 6.–Dams in the Au Sable River watershed, sorted by county. Date is date of construction; location is provided by township (T.), range (R.), and section (Sec.); "Owner" indicates ownership as private, state, or local government; * indicates dam was removed; blanks indicate data are missing. Data from P. Wessel (Michigan Department of Environmental Quality, Land and Water Management, Dam Safety Section).

County Dam	River	Date	T.	R.	Sec.	Owner	Head (ft)	Pond area (acres)	Storage (acre-ft)
Otsego									
7th Spectacle Lake	W. Br. Big Ck.-North trib	1939	29N	01W	23	Private	7	38	120
Buhl	N. Br. Au Sable R.		29N	02W	7	Private		2	
Microdot Inc.	N. Br. Au Sable R.		29N	02W	7	Private		1	
Lake Tecon	Kolke Ck.	1928	29N	04W	14	Private	4	270	400
Michaywe Ltd.	N. Br. Au Sable R.		30N	03W	35	Private		2	
Otsego Lake	N. Br. Au Sable R.	1972	30N	03W	28	Local		1997	
Crawford									
Conners Marsh	Conners Marsh Ck.	1955	26N	01W	3	State	3	53	106
Bromley	Au Sable R. trib	1970	26N	02W	3	Private	6	1	
Madsen	Barker Ck.		26N	02W	2	Private		5	
Wakeley	Baker Ck.		26N	02W	2	Private	6	4	
Au Sable Hatchery Ponds	E. Br. Au Sable R.	1915	26N	03W	8	Private	2	3	2
Grayling Millpond	Au Sable R.	1933	26N	03W	7	Local	5	85	170
Grayling Game Club	Simpson Ck.	1930	26N	03W	19	Private	4	5	
Salling*	Au Sable R.	1914	26N	04W	12	Private	1	1	
Meininger	N. Br. Au Sable R. trib	1968	27N	01W	16	Private	10	5	20
Sandhill Lake	Au Sable R. trib		27N	04W	23	State			
Big Creek	M. B. Big Ck.-North	1964	28N	01W	25	State	10	97	388
Smith	N. Br. Au Sable R. trib		28N	01W	28	Private	4		
Werthermann	W. Br. Big Ck.-North trib		28N	01W	28	Private	6	3	6
Big Bradford Lake	Bradford Ck.	1979	28N	03W	6	Local	4	244	390
Old Fredric Lumber Mill*	Au Sable R.		28N	04W	35	State	2	2	

Table 6.–Continued.

County Dam	River	Date	T.	R.	Sec.	Owner	Head (ft)	Pond area (acres)	Storage (acre-ft)
Roscommon									
Beaver Lake Flooding	Marsh Ck.	1960	23N	01W	13	State	4	33	66
Lake St. Helen	S. Br. Au Sable R.	1930	23N	01W	8	Local	3.5	2400	4800
Robinson Creek Flooding	Robinson Ck.	1955	24N	02W	29	State	6	490	1300
Wyckoff	Tank Ck.		24N	02W	7	Private		1	
Ogemaw									
Au Sable Lake	S. Branch R.	1977	24N	04E	34	Local	1	271	110
Oscoda									
Hunt Creek	Hunt Ck.		25N	01E	9	Private	5	10	20
Deeter	Red Ck.	1970	26N	01E	15	Private	3	5	
Dumka	Lost Ck.	1900	26N	02E	17	Private	4	8	30
Hoy	Lost Ck. Trib		26N	02E	36	Private		3	
Miller	Lost Ck.		26N	02E	7	Private		1	
Mio	Au Sable R.	1917	26N	02E	12	Private	29	860	13900
Mio DNR Walleye Pond	Au Sable R. Trib	1985	26N	02E	10	State	10	3	14
Perma Log Co.	Wolf Ck. Trib	1900	26N	02E	36	Private	11	1	6
Pierce's Paradise	Lost Ck. Trib	1900	26N	02E	28	Private	9	1	5
Hinchman	Wolf Ck.	1937	26N	03E	7	Private	6	2	
Kerschenheiter	Loud Ck.	1900	26N	03E	20	Private	11	1	3
Maier	Wolf Ck.	1900	26N	03E	30	Private	18	4	6
Pohley	Cauchy Ck.	1987	26N	03E	22	Private	16	2	12
Demski	Beaver Ck.	1970	27N	01E	27	Private	4	1	
Glen Lake	Beaver Ck.	1975	27N	01E	27	Private	5	10	60
Grants	Wright Ck.		27N	01E	3	Private	4	2	4
Arney No 1 (Upstream)	Cherry Ck. Trib	1978	27N	02E	14	Private	8	2	5
Arney No 2 (Middle)	Cherry Ck. Trib	1978	27N	02E	14	Private	15	1	4
Arney No 3 (Downstream)	Cherry Ck. Trib	1978	27N	02E	14	Private	13	4	19
Bills	Honeywell Ck.	1961	27N	02E	35	Private	8	4	25

Table 6.–Continued.

County Dam	River	Date	T.	R.	Sec.	Owner	Head (ft)	Pond area (acres)	Storage (acre-ft)
Oscoda (continued)									
Bills East	Honeywell Ck.		27N	02E	35	Private		2	
Bills West	Cherry Ck.		27N	02E	31	Private		1	
Davis	Honeywell Ck.	1900	27N	02E	27	Private	16	4	30
Dusty L Ranch	Honeywell Ck. Trib	1900	27N	02E	21	Private	9	1	2
Ebert	Honeywell Ck.		27N	02E	21	Private	11	3	6
Gerber	Honeywell Ck. Trib		27N	02E	26	Private		2	
MI No Name #15	Honeywell Ck. Trib	1970	27N	02E	28	Private	8	1	4
Shafer	Cherry Ck.	1970	27N	02E	24	Private	9	1	2
Whitmarsh	Cherry Ck. Trib	1967	27N	02E	13	Private	11	1	1
Wright	Au Sable R. Trib		27N	02E	33	Private		1	
Blamer	Cherry Ck.	1976	27N	03E	31	Private	15	7	40
Bosco	Perry Ck.	1949	27N	03E	33	Private	3	2	2
Gusler Creek Lower	Gusler Ck.		27N	03E	16	Private	4	1	
Gusler Creek Upper	Gusler Ck.		27N	03E	16	Private	4	1	
Miller	Perry Ck. Trib	1970	27N	03E	21	Private	15	2	
Monroe	Perry Ck.	1970	27N	03E	21	Private	18	2	16
Morgan	Perry Ck.	1965	27N	03E	21	Private	4	1	2
Okie Kauffman	Gusler Ck.	1975	27N	03E	21	Private	16	6	40
Polarski	Perry Ck.	1963	27N	03E	16	Private	4	4	6
Reuel Detweiler (Lower)	Perry Ck. Trib	1977	27N	03E	16	Private	8	6	22
Sherwood Corners	Cherry Ck.	1950	27N	03E	30	Private	13	4	16
Troyer	Perry Ck. Trib		27N	03E	22	Private	5	1	
Wise	Perry Ck. Trib		27N	03E	16	Private	3	1	
East Branch	E. Br. Big Creek-North	1880	28N	01E	33	State	7	5	14
Lower Boron	Wright Ck.		28N	01E	34	Private	6	7	17
Upper Boron	Wright Ck.	1962	28N	01E	34	Private	6	14	33

Table 6.–Continued.

County Dam	River	Date	T.	R.	Sec.	Owner	Head (ft)	Pond area (acres)	Storage (acre-ft)
Alcona									
Alcona	Au Sable R.	1924	25N	05E	14	Private	39	1075	5000
Grohowski	Wallace Ck.	1970	25N	06E	27	Private	4	1	
Stier	Wallace Ck.	1958	25N	06E	26	Private		1	
Tisdale	Kurtz Ck.		25N	06E	13	Private			
Bryant Lake	Bryant Ck.	1933	25N	06E	36	Private	5	6	22
Droz	McGillis Ck. Trib.	1969	25N	07E	2	Private	8	1	
Hertzlers	Samyn Ck.	1923	25N	07E	7	Private	4	2	
Jennings	Bryant Ck.	1966	25N	07E	19	Private		1	
Pine River Camp Grounds Dam	S. Br. Pine R.		25N	07E	16	Federal		1	
Buhl	S. Br. Pine R.	1933	25N	08E	8	Federal	4	4	25
Waszkiewicz*	Grey Ck.	1967	25N	08E	29	Private			
Golden Arrow Campground Dam	Hill Ck.	1972	25N	08E	34	Private		5	
Golden Arrow Campground	Grey Ck.		25N	08E	9	Private			
Rippy	Duval Ck.	1974	25N	08E	33	Private	13	1	
Schrade	E. Br. Pine R. Trib		25N	08E	2	Private		1	
Barlow	Van Etten Ck.		25N	08E	12	Private		1	
Big Gulch Pond	Wilbur Ck. Trib	1996	25N	05E	7	Federal	9	10	
Outlaw Pond	Wilbur Ck. Trib	1996	25N	05E	18	Federal	7	18	
Otter Pond	Smith Ck. Trib	1996	25N	05E	19	Federal	8.5	11	
Burger	Loud Ck. Trib	1970	26N	06E	11	Private		3	
Sprinkler Lake	McGillis Ck. Trib.		26N	07E	32	Federal			
Lahoony	W. Br. Pine R. Trib		26N	07E	19	Private	20	5	30
Jewell Lake	Backus Ck. Trib		26N	07E	4	Private		180	
Thomas	W. Br. Pine R. Trib	1971	26N	07E	14	Private		2	
Unkovich	W. Br. Pine R. Trib	1968	26N	07E	23	Private		2	
Kerlin	Backus Ck.		26N	07E	10	Private		3	
Gimlet Creek No. 1	Gimlet Ck.		26N	07E	36	Private		3	

Table 6.–Continued.

County Dam	River	Date	T.	R.	Sec.	Owner	Head (ft)	Pond area (acres)	Storage (acre-ft)
Alcona (continued)									
Gimlet Creek No. 2	Gimlet Ck.		26N	07E	36	Private		1	
Mc Gillis Creek	McGillis Ck.	1992	26N	07E	30	Federal	6	14	
Pine River	Pine R.		26N	08E	10	Private		1	
Lewis, Temby & Buck	E. Br. Pine R.		26N	08E	34	Private		1	
Tait North	E. Br. Pine R.		26N	08E	34	Private		1	
Tait South	E. Br. Pine R.		26N	08E	34	Private		1	
Apsey	Van Etten Ck.		26N	09E	7	Private		1	
Iosco									
Five Channels	Au Sable R.	1912	24N	06E	23	Private	36	250	4700
Loud	Au Sable R.	1913	24N	06E	21	Private	27	790	11700
Cooke	Au Sable R.	1912	24N	07E	15	Private	39	1650	36700
Foote	Au Sable R.	1918	24N	08E	35	Private	39	1570	37000
Van Etten Lake Dam	Pine R.	1947	24N	09E	27	Local	4	1320	2100
Simpson Dam	Huron Ck.	1930	24N	09E	5	Private	8	25	80

Table 7.–Estimated entrainment and mortality of fish in 1991 at six hydropower dams on the lower Au Sable River. Estimates from Lawler, Matusky, and Skelly Engineers (1991 a, b, c, d, e, f). Economic values are from Michigan Department of Natural Resources and Environmental code, Public Act 451, Part 487, 1994 which contains codified values for damages to wildlife and fisheries, and the American Fisheries Society (AFS) replacement values of freshwater fish (Anonymous 1982), adjusted upward for inflation (1983-91, 1.38 times higher). *estimates on average length were from Loud Pond, Foote Pond and Mio Pond. **estimates on average length were from Loud and Mio ponds. UNID = unidentified.

Project & species	Number entrained	Mortality (%)	Number killed	Biomass killed (lbs.)	P.A. 451 restitution	AFS value
Mio	120082	25	30232	12698.6	$297,419.52	$91,556.41
Alcona	89887	22	19615	6958.8	$173,490.36	$30,420.56
Loud	162363	17	28143	1362.7	$223,707.37	$30,094.11
Five Channels	427333	16	66859	3764.2	$561,976.97	$64,605.60
Cooke	222423	22	48159	2616.3	$400,856.07	$34,490.85
Foote	154954	24	37478	70838.9	$825,977.74	$147,544.96
GRAND TOTALS	1177043	20	230487	98239.5	$2,483,428.02	$398,712.49
Mio Project						
Bowfin	842	8	67	104.4	$522.20	$26.95
White sucker	19131	8	1531	948.9	$4,744.58	$841.78
Golden redhorse	2045	8	164	142.4	$711.83	$90.00
Shorthead redhorse	842	8	67	58.6	$293.11	$37.06
Moxostoma spp	842	8	67	47.8	$239.20	$37.06
Rock bass	23343	13	3035	1942.1	$30,345.46	$8,375.35
Pumpkinseed	361	13	47	3.3	$469.26	$38.01
Bluegill	9866	13	1283	153.9	$12,826.43	$1,770.05
Smallmouth bass	33570	23	7721	1544.2	$77,211.27	$18,144.65
Largemouth bass	842	23	194	106.5	$1,937.20	$821.37
Centrachidae UNID	361	13	47	6.1	$469.26	$64.76
Northern redbelly dace	361	41	148	1.5	$7.40	$11.84
Northern pike	361	49	177	1064.8	$12,381.24	$1,078.94
Yellow bullhead	842	8	67	17.5	$87.60	$32.34
Brown bullhead	842	8	67	2.7	$13.48	$14.82
Yellow perch	3249	40	1299	233.9	$12,994.88	$1,130.55

Table 7.–Continued.

Project & species	Number entrained	Mortality (%)	Number killed	Biomass killed (lbs.)	P.A. 451 restitution	AFS value
Mio Project (continued)						
Walleye	19131	72	13775	6198.6	$137,745.77	$53,032.12
UNID Percidae	361	69	249	2.5	$2,490.69	$72.23
Menominee	1685	5	84	31.2	$842.26	$128.02
Brown trout	842	5	42	94.3	$1,263.39	$109.92
UNID	361	28	101	1.0	$1,010.71	$101.07
TOTALS	120082		30232	12698.6	$297,419.52	$91,556.41
Alcona Project*						
Bowfin	540	8	43	243.2	$1,215.77	$17.28
White sucker	19345	8	1548	1655.9	$8,279.68	$851.18
Longnose sucker	540	8	43	45.8	$228.90	$23.75
Moxostoma spp	540	8	43	59.6	$298.00	$23.75
Rock bass	23844	8	1908	3109.2	$38,150.25	$5,264.73
Bluegill	11157	13	1450	130.5	$14,504.29	$1,377.91
Smallmouth bass	3509	13	456	54.7	$4,561.83	$816.57
Northern hog sucker	540	8	43	48.8	$244.02	$23.32
Black crappie	1530	8	122	11.0	$1,223.69	$168.87
Sand shiner	1530	41	627	6.3	$31.36	$50.17
Spottail shiner	5039	41	2066	20.7	$103.29	$165.27
Brook stickleback	990	41	406	1.6	$7.82	$32.46
Yellow perch	8638	40	3455	103.7	$34,551.17	$1,278.39
Walleye	9628	72	6932	1455.7	$69,318.28	$21,557.99
Logperch	990	40	396	1.4	$7.19	$31.67
Rainbow trout	1530	5	76	10.7	$764.80	$60.42
TOTALS	89887		19615	6959	$173,490.36	$30,420.56
Loud Project**						
Pirate perch	2600	25	650	13	$65.01	$52.01
Black crappie	13327	9	1199	12	$11,994.42	$707.67
Bluegill	13327	9	1199	204	$11,994.42	$1,655.23

Table 7.–Continued.

Project & species	Number entrained	Mortality (%)	Number killed	Biomass killed (lbs.)	P.A. 451 restitution	AFS value
Loud Project (continued)						
Rock bass	64035	9	5763	173	$57,631.72	$3,746.06
Smallmouth bass	7964	23	1832	55	$18,316.68	$2,179.68
Carp	2600	20	520	42	$208.03	$41.61
Creek chub	2600	64	1664	17	$83.21	$133.14
Spottail shiner	2600	64	1664	50	$249.64	$133.14
Logperch	5363	25	1341	13	$67.04	$107.27
Walleye	42744	26	11114	667	$111,135.28	$20,226.62
Yellow perch	2600	25	650	117	$6,501.04	$ 565.59
UNID	2600	21	546	1	$5,460.87	$546.09
TOTALS	162363		28143	1363	$223,707.37	$30,094.11
Five Channels Project**						
Rock bass	142160	9	12226	489.0	$122,257.30	$9,902.84
Pumpkinseed sunfish	28603	9	2460	172.2	$24,598.30	$2,336.84
Bluegill	35433	9	3047	518.0	$30,472.60	$4,205.22
Smallmouth bass	92639	23	21307	639.2	$213,068.80	$25,355.19
Yellow perch	28603	25	7179	1292.3	$71,792.80	$6,245.97
Walleye	28603	26	7465	447.9	$74,653.10	$13,586.86
Black crappie	28603	9	2460	98.4	$24,598.30	$2,115.45
Logperch	28603	25	7179	71.8	$358.96	$574.34
Blackside darter	14088	25	3536	35.4	$176.80	$282.88
TOTALS	427333		66859	3764	$561,976.97	$64,605.60
Cooke Project**						
Black crappie	27136	9	2442	24.4	$24,422.05	$1,440.90
Rock bass	16014	9	1441	173.0	$14,413.01	$1,369.24
Spottail shiner	12678	64	8114	81.1	$405.70	$649.12
UNID	8897	21	1868	18.7	$18,683.53	$1,868.35
Pumpkinseed sunfish	4671	9	420	37.8	$4,203.79	$399.36
Bluegill	4671	9	420	71.5	$4,203.79	$580.12

Table 7.–Continued.

Project & species	Number entrained	Mortality (%)	Number killed	Biomass killed (lbs.)	P.A. 451 restitution	AFS value
Cooke Project (continued)						
UNID centrachidae	1557	9	140	23.8	$1,401.26	$193.37
Muskellunge	20685	9	1862	204.8	$18,616.81	$8,787.13
Smallmouth bass	4671	23	1074	182.6	$10,743.03	$2,524.61
Yellow perch	119886	25	29971	1798.3	$299,714.99	$16,484.32
Walleye	1557	26	405	0.3	$4,048.10	$194.31
TOTALS	222423		48159	2616	$400,856.07	$34,490.85
Foote Project						
White sucker	75542	8	6043	12811.9	$64,059.54	$3,323.84
Longnose sucker	2632	8	211	261.1	$1,305.27	$115.79
Chestnut lamprey	929	8	74	7.4	$37.15	$5.94
Northern hog sucker	929	8	74	84.0	$419.81	$40.87
UNID crappie	929	13	121	12.1	$1,207.43	$166.63
Black crappie	4180	13	543	54.3	$5,433.44	$749.82
Rock bass	10372	13	1348	188.8	$13,482.99	$1,860.65
Bluegill	929	13	121	0.4	$1,207.43	$68.82
Smallmouth bass	17183	23	3952	2568.8	$39,520.18	$19,088.25
Muskellunge	929	49	455	95.6	$4,551.09	$4,318.98
Yellow perch	2632	40	1053	94.7	$10,526.33	$684.21
Northern pike	1703	49	834	116.8	$8,343.67	$2,302.85
Channel catfish	3406	8	272	335.1	$5,448.92	$465.88
Walleye	30960	72	22291	53052.7	$668,731.68	$114,130.21
Brown trout	1703	5	85	164.3	$1,702.79	$222.21
TOTALS	154954		37478	70838.93	$825,977.74	$147,544.96

Table 8.–Estimated smolt production and adult run size for several Great Lakes fishes in the Au Sable River after dam removal. Estimates were made for the river from Mio Dam to the river mouth, with reaches categorized by their present status (riverine or impounded). Estimates of smolt production and adult run size were based on relationships between stream discharge, gradient, and fish abundance developed by G. Whelan (MDNR, Fisheries Division records) using data from published studies (Carl 1982; Seelbach 1986; Thuemler 1985; Auer 1995; Auer 1996) and unpublished data (R. O'Neal, MDNR, Fisheries Division, unpublished data). Additional estimates of annual production of June young-of-year (YOY) chinook salmon and September YOY steelhead were made for portions of each reach having >4.6 ft/mi gradient using relationships based on data from the Manistee River below Tippy Dam (Rutherford et al. 1997).

Reach	Total miles	Miles >3 ft/mi	Miles >5ft/mi	Chinook smolts	Steelhead smolts	Lake sturgeon adult run	Miles >4.6ft/mi	June YOY chinook	Sept. YOY steelhead
Foote-Lk Huron riverine	10.2	0.0	0.0						
Foote Pond	15.0	3.2	0.0	169,600	54,880	0	0.0		
Cooke Pond	15.0	4.5	0.0	238,500	77,175	0	0.0		
Five Channels Pond	3.6	3.6	3.6	190,800	61,740	6,840	3.6	3,194,726	89,510
Loud Pond	7.3	4.1	4.1	217,300	70,315	7,790	4.1	3,638,438	101,942
Alcona-Loud riverine	10.3	10.3	0.8	545,900	176,645	1,520	2.9	2,573,530	72,106
Alcona Pond	8.1	5.5	2.7	291,500	94,325	5,130	2.7	2,396,045	67,133
Mio-Alcona riverine	23.5	19.9	6.8	1,054,700	341,285	12,920	8.8	7,809,331	218,803
TOTAL	93.0	51.1	18.0	2,708,300	876,365	34,200	22.1	19,612,070	549,494
Production by water type									
Riverine	44.0	30.2	7.6	1,600,600	517,930	14,440	11.7	10,382,861	290,909
Impounded	49.0	20.9	10.4	1,107,700	358,435	19,760	10.4	9,229,210	258,586

Assumptions for making smolt production and adult run estimates:

Stream discharge: mean annual flow of >1000 cfs
At gradients >3 ft/mi: Smolt production (#/mi): Chinook salmon- 2650; Steelhead- 1715; Adult walleye run = 6599 fish/mi
At gradients >5 ft/mi gradient: Adult lake sturgeon run = 1900 fish/mi; Other species: same as above

Table 9.–Historical water quality data for stream sites in the Au Sable River watershed having extensive data on dissolved metals. Data from S. Holden (Michigan Department of Environmental Quality, Surface Water Quality Division). * indicates dissolved concentration, not total.

Period of data collection:	1966-75		1992		1966-71		1966-92		1958-81		1973-92	
Stream:	Au Sable River		N. Branch		E. Branch		S. Branch		Au Sable River		Pine R.	
Location:	Stephan's Br.		Co. Rd. 612 (Lovells)		N. Down River Rd.		M-72		US-23		F-41 (below Van Etten Lake)	
Parameter	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n
Stream discharge (cfs)	136	62					275	5	1892	172	180	85
Tubidity (JTU)	2.3	19							3.2	47	6.1	10
Turbidity-meter (Hach ftu)	1.4	8	1.1	7			1.1	8			4.2	86
Conductivity at 25C (umho)	313	32	301	7	290	2	252	13	288	122	321	96
DO (% saturation)	88.7	55			84.4	21	86.5	18	87.0	151	91.1	89
BOD 5-day total (mg/l)	2.9	66			0.9	14	1.2	10	1.7	130	2.5	88
COD-low-level chemical oxygen demand (mg/l)	6.1	2			8.0	1	8.0	1	11.2	49	19.1	70
pH (su)	8.0	36	8.3	7	8.2	2	8.0	13	8.1	146	8.2	96
pH-lab (su)	7.9	6							7.9	1	7.8	7
Total alkalinity ($CaCO_3$ mg/l)	134	27	140	7	145	1	110	7	141	46	151	71
Organic nitrogen (N mg/l)	0.42	32			0.70	1	0.42	3	0.31	36	0.50	89
Ammonia (mg N/l)	0.140	33	0.024	7	0.005	2	0.009	11	0.057	135	0.031	96
Total nitrite (NO_2 mg/l)			0.002	7	0.010	1	0.002	8			0.005	7
Total nitrate (mg N/l)	0.081	7	0.038	7	0.100	2	0.058	8	0.088	127	0.152	7
Nitrate + nitrite (mg N/l)	0.135	26	0.040	7			0.060	10	0.059	8	0.127	96
Total phosphorus (mg P/l)	0.032	30	0.024	7	0.030	1	0.017	10	0.048	65	0.032	96
Total cyanide (CN mg/l)	0.0133	3							0.0080	5	0.0067	11
Total hardness ($CaCO_3$ mg/l)	144	27	147	7	160	1	121	7	157	51	167	71
Total calcium (mg/l)	42.5*	2	42.3	7	50.0*	1	34.4	7	46.0	2	46.1	15
Magnesium, total (mg/l)	10.0	1	10.1	7	8.8*	1	8.5	7	11.0	2	13.1	15
Total sodium (mg/l)	5.3	1	3.1	1	2.6*	2	5.0	1	4.8	2	5.3	9
Total potassium (mg/l)	0.47	1	0.31	1	0.45*	2	0.35	1	0.40	2	1.05	9
Chloride, dissolved (mg/l)	16.6	30	3.0	7	6.0	2	5.7	9	3.9	149	6.4	96
Total sulfate (SO_4 mg/l)	7.3*	4	5.0	1	10.0*	2	8.0	1	14.9*	17	7.4	2

Table 9.–Continued.

Period of data collection:	1966-75		1992		1966-71		1966-92		1958-81		1973-92	
Stream:	Au Sable River		N. Branch		E. Branch		S. Branch		Au Sable River		Pine R.	
Location:	Stephan's Br.		Co. Rd. 612 (Lovells)		N. Down River Rd.		M-72		US-23		F-41 (below Van Etten Lake)	
Parameter	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n
Fluoride, dissolved (mg/l)	0.12	4			0.11	1			0.14	5	0.19	3
Silicate- UNF REAT (Si mg/l)	3.50	26			3.30	1			3.92	34	3.67	89
Total arsenic (As ug/l)	1*	5	1	7	10*	1	2	7	1*	3	1	12
Total barium (Ba ug/l)			15	1			17	1			23	3
Total berylium (Be ug/l)			1	1			1	1			1	1
Total cadmium (Cd ug/l)	1.7*	6	0.2	7	2*	1	0.2	7	0.8*	4	0.7	12
Chromium- HEX-VAL (ug/l)	10	3	5	7			5	7	6	5	7	12
Total chromium (Cr ug/l)			1	7	10	1	1	7			2	12
Total cobalt (Co ug/l)			15	1			15	1			15	1
Total copper (Cu ug/l)	1*	5	1	7	6*	1	1	7	2*	4	2	12
Total iron (ug/l)	100	1	190	1	200	1	185	2	167	12	215	31
Total lead (Pb ug/l)	2*	5	1	7	10*	1	1	7	2*	3	4	12
Total manganese (Mn ug/l)	5*	2	32.00	1			43.00	1	26.67	3	30.57	7
Total molybdenum (Mo ug/l)			25	1			25	1			25	1
Total nickel (Ni ug/l)	13*	5	2	7	10*	1	2	7	3*	4	4	12
Total silver (Ag ug/l)	3*	2	0.5	7			0.5	7	3*	2	0.9	12
Total vanadium (V ug/l)			10	1			10	1			10	1
Total zinc (Zn ug/l)	30*	4	6	7	10*	1	5	7	11*	5	9	12
Total antimony (Sb ug/l)			1	1			1	1			1	1
Total aluminum (Al ug/l)			50	1			50	1			120	1
Total lithium (Li ug/l)			8	1			8	1			7	5
Total selenium (Se ug/l)	2.3*	3	1.0	1			1.0	1	1.0*	2	1.1	5
Total titanium (Ti ug/l)			15	1			15	1			53	5
Total coliform- MFIM LES (/100 ml)	3689	35			3593	14	214	7	5688	90	1525	41
Fecal coliform (MFM-FCBR/100ml)	95	44			2143	10	198	5	200	86	45	90

Table 9.–Continued.

Period of data collection:	1966-75		1992		1966-71		1966-92		1958-81		1973-92	
Stream:	Au Sable River		N. Branch		E. Branch		S. Branch		Au Sable River		Pine R.	
Location:	Stephan's Br.		Co. Rd. 612 (Lovells)		N. Down River Rd.		M-72		US-23		F-41 (below Van Etten Lake)	
Parameter	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean	n
Chlorophyll a (ug/l)											10.9	79
Total phenols (ug/l)	2.0	5							1.6	5	2.4	32
Calcium hardness (Ca mg/l)			147	7	161	1	121	7	158	18	169	15
Total dissolved solids- E.C. (mg/l)	214	30	196	7	218	1	166	8	188	44	209	96
Ortho phosphate (P mg/l)	0.013	30			0.010	1	0.012	3	0.017	129	0.008	89
Total mercury (ug/l)	0.1	5			0.2	1			0.2	4	0.5	11

Table 10.–Historical water quality data for stream sites in the Au Sable River watershed lacking extensive data on dissolved metals. Data from S. Holden (Michigan Department of Environmental Quality, Surface Water Quality Division).

Period of data collection:	1967-70		1966		1966		1966	
Stream:	Pine River		Big Creek-South		Au Sable River		Au Sable River	
Location:	F41 (above Van Etten Cr.)				F-97 (above North Br.)		Co Rd 487 (above Mio Pd.)	
Parameter	Mean	n	Mean	n	Mean	n	Mean	n
Stream discharge (cfs)	148	2						
Conductivity at 25C (umho)	400	1	290	1	270	1	280	1
DO (% saturation)	98.2		90.3	14	92.0	14	86.5	14
BOD 5-day total (mg/l)	2.3	1	1.0	7	1.2	7	1.1	7
COD-low-level chemical oxygen demand (mg/l)			14.0	1	6.0	1	7.0	1
pH (su)	8.4	2	8.3	1	8.3	1	8.3	1
Total alkalinity ($CaCO_3$ mg/l)	188	2						
Ammonia (mg N/l)	0.02	2	0.000	1	0.000	1	0.000	1
Total nitrite (NO_2 mg/l)			0.000	1	0.010	1	0.000	1
Total Nitrate (mg N/l)	0.075	2	0.000	1	0.000	1	0.000	1
Total Phosphorus (mg P/l)	0.030	2						
Total hardness ($CaCO_3$ mg/l)	197.500	2						
Calcium, dissolved (mg/l)	52.000	2						
Magnesium, dissolved (mg/l)	16	2						
Sodium, dissolved (mg/l)	6.2	2	3.3	1	3.2	1	3.2	1
Potassium, dissolved (mg/l)	1	2	0.4	1	0.4	1	0.4	1
Chloride, dissolved (mg/l)	5.5	2	0.0	1	2.0	1	1.0	1
Sulfate, dissolved (mg/l)	16	2	13.0	1	7.0	1	9.0	1
Fluoride, dissolved (mg/l)	0.325	2						
Total iron (ug/l)	200	2	100	1	200	1	200	1
Total coliform- MFIM LES (/100 ml)	100	1	129	7	1286	7	186	7

Table 11.–Recent summer water quality for sites in the Au Sable River watershed. 1997 data from G. Kohlepp (Michigan Department of Environmental Quality, Surface Water Quality Division). 1994 data from United States Geological Survey is noted with an *. T = detected but below quantification value.

Stream:	Au Sable	South Br.	South Br.	North Br.	North Br.	Big Cr.-N.	East Br.	Big Cr.-S.	Au Sable*
Location:									10.4 mi
Parameter	Grayling (Penrod's)	M18	M72	N. Down River Rd.	Twin Br. Rd.	N. Down River Rd.	Lewiston Grade Rd.	Brown Cabin Rd.	above mouth
BOD 5-day total (mg/l)	<2	<2	<2	<2	<2	<2	<2		
COD-chemical oxygen demand (mg/l)	10	11	<5	<5	8	10	10	10	
Nitrite (mg N/l)	0.002	0.003	0.002	T	T	T	0.004	T	<0.010
Nitrate + Nitrite (mg N/l)	0.038	0.035	0.056	T	T	0.010	0.165	0.033	<0.050
Ammonia (mg N/l)	T	0.016	T	T	T	T	0.018	T	0.030
Kjeldahl nitrogen (mg N/l)	0.27	0.25	0.15	0.19	0.20	0.23	0.25	0.12	
Ortho phosphate (mg P/l)	T	0.003	T	T	0.003	T	T	0.003	<0.010
Total phosphorus (mg P/l)	0.010	0.016	0.013	0.010	0.016	0.014	0.012	0.012	0.030
Suspended solids (mg/l)	5	<4	<4	5	<4	5	<4	<4	
Total dissolved solids (mg/l)	176	192	184	176	180	180	220	198	171
TOC-total organic carbon (mg/l)	3.6	4.4	2.3	3.6	3.2	3.9	3.6	2.1	

Table 12.–Range in water quality values observed in Michigan streams. Data do not include highly urbanized rivers, such as the Rouge or Clinton rivers. Data from O'Neal (1997) and G. Kohlepp (Michigan Department of Environmental Quality, Surface Water Quality Division, personal communication).

Parameter	Range of values
DO (% saturation)	75-120
BOD 5-day total (mg/l)	0.5 - 5.0
Total dissolved solids- E.C. (mg/l)	100 - 400
pH (su)	7.5 - 8.5
Total alkalinity ($CaCO_3$ mg/l)	40 - 200
Total hardness (mg/l $CaCO_3$)	50 - 250
Specific conductivity (umho at 25^o C)	100 - 600
Ammonia (mg N/l)	0.005 - 0.1
Total nitrite (NO_2 mg/l)	0.002 – 0.04
Total nitrate (mg N/l)	< 2.0
Nitrate + nitrite (mg N/l)	0.005 - 2
Total Kjeldahl nitrogen (mg/l)	0.2 – 1.0
Total phosphorus (mg P/l)	0.01 - 0.15
Ortho phosphate (P mg/l)	0.002 – 0.1
Chlorophyll a (ug/l)	1 - 75
Total chloride (mg/l)	2 - 80
Total sulfate (SO_4 mg/l)	7 - 30
Fluoride, dissolved (mg/l)	< 0.2
Total barium (Ba ug/l)	< 50
Total cadmium (ug/l)	0.0001 – 0.8
Total calcium (mg/l)	15 - 80
Total chromium (Cr ug/l)	0.2 - 4.3
Total copper (Cu ug/l)	0.15 - 4
Total iron (ug/l)	< 300
Total lead (Pb ug/l)	0.1 - 4
Total manganese (Mn ug/l)	< 40
Total mercury (ug/l)	< 0.2
Total nickel (Ni ug/l)	1.0 - 5.0
Total selenium (Se ug/l)	< 5
Total zinc (Zn ug/l)	0.2 - 12
Total phenols (ug/l)	0.2 – 2.0

Table 13.–National Pollution Discharge Elimination System (NPDES) permits issued in the Au Sable River watershed.

County and permittee	Location
Roscommon	
ITT-Hancock Industries Inc.	Robinson Creek
Roscommon Waste Water Treatment Plant	South Branch Au Sable River
Alcona	
Consumers Energy Company- Alcona Hydro Plant	Au Sable River
Steadman Brothers Oil Company	Pine River
Viking Energy of Lincoln	East Branch Pine River
Iosco	
Consumers Energy Company- Loud Hydro Plant	Au Sable River
Consumers Energy Company- Five Channels Hydro Plant	Au Sable River
Consumers Energy Company- Cooke Hydro Plant	Au Sable River
Consumers Energy Company- Foote Hydro Plant	Au Sable River
Consumers Energy Company- Mio Hydro Plant	Au Sable River
Oscoda Township Waste Water Treatment Plant	Au Sable River
Wurtsmith Air Force Base	Au Sable River
Hedblum Industries Superfund Site	Old Au Sable River

Table 14.–Contaminated sites in the Au Sable River watershed by county, from headwaters to the mouth, as of April 1998. Data from Michigan Department of Environmental Quality, Environmental Response Division, Public Act 451, Part 201. Acronyms: BTEX = benzene, toluene, ethylbenzene, xylene; BTX = benzene, toluene, xylene; DCA = dichloroethane; 1,1 DCA = 1,1 dichloroethane; 1,2 DCA = 1,2 dichloroethane; cis-1,2 DCA = cis-1,2 dichloroethane; DCE = dichloroethylene; 1,1DCE = 1,1 dichloroethylene; DDD = dischlorodiphenyldichloroethane; MEK = methyl ethyl ketone; MTBE = methyl(tert)butylether; PAH = polyaromatic hydrocarbon; PCB = polychlorinated biphenyls; PCE or PERC = perchloroethylene; PNAs = polynuclear aromatic hydrocarbons; TCA = trichloroethane; 1,1,1 TCE = isomer of previous; TCE = trichlorethylene.

County and common site name	Pollutant
Otsego	
Bagley 35 Central Production	Crude Oil, BETX
Chester Twp Hydrocarbon Spill	BTEX, napthalene, asbestos
Construction Board	Di-n-butylphalate, ammonia, formaldehyde
Former Northern Autobody	Arsenic, toluene, acetone, PCE, MIEK, MEK
Gas Dehydration Site	BTEX
Gas Dehydration Site	BTEX
Gaylord Repair Facility	BTEX, PNAs, TCE
Gaylord Waste Water Treatment Plant -City	Nitrates, Dissolved Solids
Jaruzel 7-18	Brine/Chloride
Lake Tecon Property	Fuel oil
Leacock et. al.	Benezene, Toluene
Marcenkowski 6-17 10/12/90	Brine/Chloride
Mobil Oil Company	Naphthalene, Flourene, Acenaphthene, BTEX
Northern Energy Inc.	Petroleum Products
Northern Tank Truck Services	Brine
Old Gaylord Dump Closed	Domestic, Commercial
Residential Well Johnson Road	Brine
Standard Products	Sodium nitrate
State Chester WI-36	Brine/Chloride
State-Bagley #4-25	Benzene, Toluene
517 Alpine Road	Fluorene, acenaphtylene
Crawford	
Al Bennett Ford	Tetrachloroethylene, 1,2 Dichloroethylene
Barber St. GW	BTEX
Camp Grayling 616B	Toluene, ethylbenzene, xylene isomers
Camp Grayling Bulk Fuel Facility	PCE, TCE
City Environmental Services of Waters	Benzene, Iron, Vinyl Chloride
City of Grayling Wastewater Treatment Facility	Nitrate
Crawford County Jail Property	PNAs Dibenzofuran
Frederic TWP GW Contamination	BTEX
Modular Engineering	BTEX
Old Mill Property	Benzo(a)pyrene, flouranthene
Shepan Fuel Oil Spill	Heating Oil, Ethylbenzene
Shell Oil Co. Abandoned Brine Pit	Brine
S. Branch Twp, M18 Residential Well	BTEX
Straits Wood Treating	Arsenic, Copper, Chromium
Wyandotte Lodge	Heating Oil

Table 14.–Continued.

County and common site name	Pollutant
Oscoda	
Chlorides Residential Well, Fairview	Chlorides
Garland Golf Course	Toluene-acenophthlene
Hoskins Manufacturing	Brine
MDOT Mio Garage	BTEX
Oscoda Co Fairgrounds	Dichloroethylene
Oscoda Co Rd Commission, Mio	Salt
Residential Well Schild, Luzerne	BTEX, cychohane n-pentane
Washout Laundry Lagoons	Perchlorethylene
Washout Laundry	PCE, TCE, DCE
Residential Well, Fairview	BTEX
Montmorency	
Gas Station GW Contamination, Albert Twp.	Trichloroethane
Lewiston Laundromat	Chloroform, TCE
Pine Beach Subdivision Fuel	Fuel Oil
Roscommon	
909 Lake Street	Benzene, Xylenes, Naphthalene
Abandoned Bulk Fuel Storage Plant	Ethylbenzene, xylene, benzene, naphthalene
Au Sable Cleaners Former	Stoddard Solvent
Barbier Bulk Oil Plant	BTEX
Block 10 Lot 3 Roscommon Village	BTEX, Naphthalene, 135-Trimethylbenzene
DNR Forest Fire Experiment Station	Toxaphene, DDT
Former Gas Station 709 Lake Street	Benzene, Xylenes
ITT Hancock Industries	Cadmium, chromium, copper, nickel, zinc, PERC
Liquid Transport Crude Oil Spill	Benzene, Crude Oil
Roscommon Co Rd Comm	Salt
Roscommon, Village of	BTEX
St. Helen Bulk Oil Plant	BTEX
Sun Company Inc. (R&M)	Crude Oil
St. Helen C.T.B.	Condensate-BTEX, Crude Oil
Total Pipeline Corporation	Crude Oil
Alcona	
Alcona County Road Commission	Salt
Alcona County Landfill	Lead, Chlorides
Glennie Storm Drains	Trichloroethene
Huron Tool	Coolant sludge
Iron Skillet Lincoln	Benzene
Lincoln Village Hardware	Xylene, Benzene
Ron’s Repair	BTEX
Viking Energy	BTEX
Iosco	
Au Sable Beaver Pond	DCE, TCE
Au Sable Huron Condo Campground	Benzene, Toluene
C and S Trucking	Chemical products from manufacturing
Easy Way Cleaners Former	PCE, DCE, TCE, Vinyl Chloride

Table 14.–Continued.

County and common site name	Pollutant
Iosco (continued)	
Hedblum Industries	TCA; 1,1,1 TCE
Kaul Glove and Manufacturing	Bis(2-ethylhexyl)-phthalate, Arsenic
NSI Cleaners Former	PCE, TCE, DCE
Oscoda Manufacturing Former	Lead, chromium, nickel, xylene
Residential Wells Bachman Road	PCE, TCE, Benzene
Slobodnik Fuel Oil	Benzene, Home Heating Oil
Wurtsmith AFB 3 Pipes Drain	Trichloroethylene
Wurtsmith AFB Arrow Street Plume	Trichloroethylene
Wurtsmith AFB Building 43 SP13	Jet fuel
Wurtsmith AFB Building 5009	Jet fuel
Wurtsmith AFB Crash Site	Jet fuel
Wurtsmith AFB Fire Training Area #2	BTEX, 1,1DCE, 1,2Dichlorobenzene
Wurtsmith AFB Inactive Waste Water Treatment Plant	TCE
Wurtsmith AFB Locomotive Shop	Oil, grease
Wurtsmith AFB Jet Engine Building	BTEX, TCE, waste oil
Wurtsmith AFB MOGAS Spill SP-12	Gasoline
Wurtsmith AFB Northern Landfill	Benzene, TCE, Vinyl Chloride
Wurtsmith AFB Parking Spot 19	BTEX, Jet fuel
Wurtsmith AFB POL SS-06	BTEX, Jet fuel
Wurtsmith AFB SAC Ramp	Benzene, Toluene
6182 N. F41, Oscoda	TCE, DCE

Table 15.–Stream sections designated as State Natural Rivers in the Au Sable River watershed. Ninety-eight miles are designated on the mainstem and 251 miles on tributaries. Data from Anonymous (1987).

Mainstem-from confluence of Kolke and Bradford creeks (T28N, R4W), downstream to Loud Dam

Kolke Creek-from outfall of Lynn Lake (T29N,R4W) to its confluence with Bradford Creek

Bradford Creek–from outfall of Big Bradford Lake (T28N, R3W) to its confluence with Kolke Creek

East Branch-from outfall of Barnes Lake (T28N, R2W) to its confluence with the Au Sable River
- South Branch-from M-76 (T23N, R1W) to its confluence with the Au Sable River
- Douglas Creek-from its source (T25N, R1W) to its confluence with the South Branch
- Thayer Creek-from its source (T25N, R2W) to its confluence with the South Branch
- Hudson Creek-from its source (T24N, R2W) to its confluence with the South Branch
- Robinson Creek-from its source (T23N, R2W) to its confluence with the South Branch
- Beaver Creek-from its source (T25N, R3W) to its confluence with the South Branch
- East Creek-from its source (T24N, R1W) to its confluence with the South Branch
- South Creek-from its source (T24N, R1W) to its confluence with the South Branch

North Branch-from Ski Slope Drive (T30N, 3W) to its confluence with the Au Sable River
- Turtle Creek-from outfall of Turtle Lake (T30N, R2W) to confluence with North Branch
- Chub Creek-from outfall of Bridge Lake (T29N, R3W) to confluence with North Branch
- Big Creek-from confluence of E. & W. branches (T27N, R1W) to confluence with E. Br. Big Creek
- West Branch Big Creek-from outfall of Caulkins Lake (T29N, R1E) to confluence with E. Br. Big Ck
- Middle Branch Big Creek-from outfall of West Twin Lake (T29N, R1E) to confluence with East Branch Big Creek
- East Branch Big Creek-from north section line of section 27 (T28N, R1E) to confluence with East Branch Big Creek
- Big Creek-from confluence of East & West branches (T26N, R1E) to confluence with Au Sable River

West Branch Big Creek-from source (T25N, R1E) to confluence with East Branch Big Creek

East Branch Big Creek-from source (T25N, R2E) to confluence with West Branch Big Creek

Sohn Creek-from source (T27N, R1E) to confluence with Au Sable River Beaver Creek-from east section line of section 26 (T27N, R1E) to confluence with Au Sable River

Wolf Creek-from source (T26N, R3E) to confluence with Au Sable River

Loud Creek-from source (T26N, R3E) to confluence with Au Sable River

Perry Creek-from outfall of Perry Lake (T27N, R3E) to confluence with Au Sable River

Comins Creek-from source (T27N, R3E) to confluence with Au Sable River

Glennie Creek-from source (T27N, R4E) to confluence with Au Sable River

Nine Mile Creek-from source (T26N, R4E) to confluence with Au Sable River

Blockhouse Creek-from source (T27N, R4E) to confluence with Au Sable River

Table 16.–Fishes in the Au Sable River watershed. Data from Bailey and Smith (1981), Lawler, Matusky, and Skelly Engineers (1991a-c, f), and University of Michigan Museum of Zoology Fisheries Division and Michigan Department of Natural Resources Fisheries Division records. Species origin: N=native; C=colonized; and I=introduced. Au Sable status: P=recent observation; O=extirpated; U=historic record, current status unknown.

Common name	Scientific name	Species origin	Au Sable status
Lampreys	Petromyzontidae		
Northern brook lamprey	*Ichthyomyzon fossor*	N	P
Silver lamprey	*Ichthyomyzon unicuspis*	N	P
American brook lamprey	*Lampetra appendix*	N	P
Sea lamprey	*Petromyzon marinus*	C	P
Sturgeons	Acipenseridae		
Lake sturgeon (threatened)	*Acipenser fulvescens*	N	P
Gars	Lepisosteidae		
Longnose gar	*Lepisosteus osseus*	N	U
Bowfins	Amiidae		
Bowfin	*Amia calva*	N	P
Freshwater eels	Anguillidae		
American eel	*Anguilla rostrata*	C	P
Herrings	Clupeidae		
Alewife	*Alosa pseudoharengus*	C	P
Gizzard shad	*Dorosoma cepedianum*	N	P
Carps and minnows	Cyprinidae		
Goldfish	*Carassius auratus*	I	P
Lake chub	*Couesius plumbeus*	N	P
Spotfin shiner	*Cyprinella spiloptera*	N	P
Common carp	*Cyprinus carpio*	I	P
Brassy minnow	*Hybognathus hankinsoni*	N	P
Common shiner	*Luxilus cornutus*	N	P
Redfin shiner	*Lythrurus umbratilis*	N	P
Pearl dace	*Margariscus margarita*	N	P
Hornyhead chub	*Nocomis biguttatus*	N	P
River chub	*Nocomis micropogon*	N	P
Golden shiner	*Notemigonus crysoleucas*	N	P
Pugnose shiner	*Notropis anogenus*	N	P
Emerald shiner	*Notropis atherinoides*	N	P
Blackchin shiner	*Notropis heterodon*	N	P
Blacknose shiner	*Notropis heterolepis*	N	P
Spottail shiner	*Notropis hudsonius*	N	P
Rosyface shiner	*Notropis rubellus*	N	P
Sand shiner	*Notropis stramineus*	N	P
Mimic shiner	*Notropis volucellus*	N	P
Northern redbelly dace	*Phoxinus eos*	N	P
Finescale dace	*Phoxinus neogaeus*	N	P

Table 16.–Continued.

Common name	Scientific name	Species origin	Au Sable status
Carps and minnows continued			
Bluntnose minnow	*Pimephales notatus*	N	P
Fathead minnow	*Pimephales promelas*	N	P
Blacknose dace	*Rhinichthys atratulus*	N	P
Longnose dace	*Rhinichthys cataractae*	N	P
Creek chub	*Semotilus atromaculatus*	N	P
Suckers	Catostomidae		
Longnose sucker	*Catostomus catostomus*	N	P
White sucker	*Catostomus commersoni*	N	P
Lake chubsucker	*Erimyzon sucetta*	I	U
Northern hog sucker	*Hypentelium nigricans*	N	P
Silver redhorse	*Moxostoma anisurum*	N	P
Golden redhorse	*Moxostoma erythrurum*	N	P
Shorthead redhorse	*Moxostoma macrolepidotum*	N	P
Greater redhorse	*Moxostoma valenciennesi*	N	P
Bullhead catfishes	Ictaluridae		
Black bullhead	*Ameiurus melas*	N	P
Yellow bullhead	*Ameiurus natalis*	N	P
Brown bullhead	*Ameiurus nebulosus*	N	P
Channel catfish	*Ictalurus punctatus*	N	P
Stonecat	*Noturus flavus*	N	P
Tadpole madtom	*Noturus gyrinus*	N	P
Pikes	Esocidae		
Northern pike	*Esox lucius*	N	P
Tiger muskellunge	*E. masquinongy x E. lucius*	N	P
Mudminnows	Umbridae		
Central mudminnow	*Umbra limi*	N	P
Smelts	Osmeridae		
Rainbow smelt	*Osmerus mordax*	C	P
Trouts	Salmonidae		
Lake herring	*Coregonus artedi*	N	P
Lake whitefish	*clupeaformis*	N	P
Pink salmon	*Oncorhynchus gorbuscha*	C	P
Coho salmon	*Oncorhynchus kisutch*	I	P
Rainbow trout	*Oncorhynchus mykiss*	I	P
Chinook salmon	*Oncorhynchus tshawytscha*	I	P
Round whitefish	*Prosopium cylindraceum*	N	P
Atlantic salmon	*Salmo salar*	I	P
Brown trout	*Salmo trutta*	I	P
Brook trout	*Salvelinus fontinalis*	I	P
Lake trout	*Salvelinus namaycush*	N	P
Arctic grayling	*Thymallus arcticus*	N	O

Table 16.–Continued.

Common name	Scientific name	Species origin	Au Sable status
Trout-perches	Percopsidae		
Trout-perch	*Percopsis omiscomaycus*	N	P
Cods	Gadidae		
Burbot	*Lota lota*	N	P
Killifishes	Cyprinodontidae		
Banded killifish	*Fundulus diaphanus*	N	P
Silversides	Atherinidae		
Brook silverside	*Labidesthes sicculus*	N	P
Sticklebacks	Gasterosteidae		
Brook stickleback	*Culaea inconstans*	N	P
Sculpins	Cottidae		
Mottled sculpin	*Cottus bairdi*	N	P
Slimy sculpin	*Cottus cognatus*	N	P
Temperate basses	Percichthyidae		
White bass	*Morone chrysops*	N	P
Sunfishes	Centrarchidae		
Rock bass	*Ambloplites rupestris*	N	P
Green sunfish	*Lepomis cyanellus*	N	P
Pumpkinseed sunfish	*Lepomis gibbosus*	N	P
Bluegill	*Lepomis macrochirus*	N	P
Longear sunfish	*Lepomis megalotis*	N	P
Smallmouth bass	*Micropterus dolomieu*	N	P
Largemouth bass	*Micropterus salmoides*	N	P
White crappie	*Pomoxis annularis*	N	P
Black crappie	*Pomoxis nigromaculatus*	N	P
Perches	Percidae		
Rainbow darter	*Etheostoma caeruleum*	N	P
Iowa darter	*Etheostoma exile*	N	P
Least darter	*Etheostoma microperca*	N	P
Johnny darter	*Etheostoma nigrum*	N	P
Yellow perch	*Perca flavescens*	N	P
Logperch	*Percina caprodes*	N	P
Channel darter (threatened)	*Percina copelandi*	N	P
Blackside darter	*Percina maculata*	N	P
River darter (endangered)	*Percina shumardi*	N	U
Walleye	*Stizostedion vitreum*	N	P
Drums	Sciaenidae		
Freshwater drum	*Aplodinotus grunniens*	N	P

Table 17.–Fish stocking in the Au Sable River watershed, 1983-1993. Data from Michigan Department of Natural Resources Fisheries Division records.

County Fish species	Location	Years	Numbers	Comments
Otsego				
Northern pike	Otsego Lake	84-93	499,000	Ongoing program
Lake sturgeon	Otsego Lake	83, 91-93	14,643	Experimental study
Tiger muskie	Otsego Lake	83, 85, 87, 89, 91	34,658	Fishery did not develop
Walleye	Otsego Lake	91-93	5,302,000	Ongoing program
Walleye	Calkins Lake	85, 88-90, 92	1,750	Ongoing program
Bluegill	Calkins Lake	85	1,400	Ongoing program
Rainbow trout	Big Chub Lake	90-93	15,836	Ongoing program
Rainbow trout	Bridge Lake	90-93	13,836	Ongoing program
Brown trout	Big Chub Lake	83-89	26,200	Switched plants to rainbow trout
Brown trout	Bridge Lake	83-89	22,700	Switched plants to rainbow trout
Crawford				
Walleye	Big Creek Impd.	88, 90, 92	13,802	Ongoing program
Walleye	Jones Lake	91, 92	7,169	Ongoing program
Rainbow trout	Au Sable River	83-88, 90-92	27,678	Natural reproduction established
Rainbow trout	E. Br. Au Sable	86	1,550	Private plant
Rainbow trout	Bright Lake	83-93	7,328	Ongoing program
Rainbow trout	Glory Lake	83-93	7,930	Ongoing program
Brook trout	Au Sable River	91, 92	3,500	To augment fishery
Brook trout	S. Br. Au Sable	86	200	Private plant
Brook trout	Sandhill Lake	90, 92, 93	3,350	Ongoing program
Hybrid sunfish	Glory Lake	85, 87, 89	6,575	Ongoing program
Oscoda				
Arctic grayling	Au Sable River	87-88	53,827	Experimental study
Rainbow trout	Au Sable River	83, 85-93	111,193	Ongoing program
Rainbow trout	Mio Pond	83-91	19,840	Fishery did not develop
Brown trout	Au Sable River	85-93	69,975	Ongoing program
Brown trout	Smith Lake	83-92	8,370	Fishery did not develop
Walleye	Mio Pond	85, 86, 89, 91, 93	159,847	Natural reproduction established
Walleye	Tea Lake	88, 90, 92	30,019	Ongoing program
Tiger muskie	Tea Lake	83-91	9,091	Fishery did not develop
Black crappie	Tea Lake	85, 86	1,503	Species introduction
Montmorency				
Tiger muskie	West Twin Lake	84, 86, 88, 90	12,527	Fishery did not develop
Ogemaw				
Northern pike	Au Sable Lake	83-86, 88-91	66,575	Unsuccessful rearing marsh stocking
Walleye	Au Sable Lake	89, 92	27,652	Ongoing program

Table 17.–Continued.

County Fish species	Location	Years	Numbers	Comments
Roscommon				
Walleye	Lake St. Helen	85, 88, 90, 92	237,911	Ongoing program
Hybrid sunfish	Lake St. Helen	83	10,000	Creating fishery
Alcona				
Northern pike	Jewell Lake	83-90	55,972	Ongoing program
Walleye	Jewell Lake	86, 88, 91	32,536	Ongoing program
Walleye	Alcona Pond	88, 90	61,093	Natural reproduction established
Walleye	Vaughn Lake	88, 90, 92	28,753	Ongoing program
Rainbow trout	Au Sable River	83, 85-93	36,554	Ongoing program
Rainbow trout	O'Brien Lake	90, 91, 92	2,196	Ongoing program
Brown trout	Au Sable River	83, 85-93	39,600	Ongoing program
Brown trout	O'Brien Lake	83-85, 90-93	4,108	Ongoing program
Arctic grayling	O'Brien Lake	88	1,334	Experimental plant
Iosco				
Tiger muskie	Cooke Pond	84-91	96,582	Fishery did not develop
Tiger muskie	Foote Pond	84-91	95,582	Fishery did not develop
Tiger muskie	Van Etten Lake	84-86, 88, 89	11,900	Fishery did not develop
Walleye	Cooke Pond	85, 87, 90, 92	129,678	Ongoing program
Walleye	Foote Pond	85, 86, 89, 91, 93	257,214	Ongoing program
Walleye	Van Etten Lake	85	46,152	Ongoing program
Yellow perch	Au Sable River	83, 85	267,913	Ongoing program
Rainbow trout	Au Sable River	83-93	654,538	Ongoing program
Steelhead	Au Sable River	93-93	2,798,183	Ongoing program
Brown trout	Au Sable River	83-93	257,886	Ongoing program
Splake	Au Sable River	87	32,000	Fishery did not develop
Lake trout	Au Sable River	85, 88	224,100	Stocking location moved offshore
Chinook salmon	Au Sable River	83, 88, 91-93	2,044,953	Ongoing program
Chinook salmon	Van Etten Creek	84-90	3,864,791	Ongoing program

Table 18.–Select Michigan Department of Natural Resources, Fisheries Division research reports published since 1959 involving trout populations in the upper mainstem, North, and South branches of the Au Sable River.

Population-level dynamics, trends, and effects of angling methods and regulations
Results of studies on Michigan trout waters with special angling restrictions (type of lure, size limit, creel limit). 1949-59. (Cooper et al. 1959)
Angling and trout populations on the North Branch of the Au Sable River, Crawford and Otsego counties, Michigan, under special and normal regulations, 1958-1963. (Shetter and Alexander 1964)
Trout production and catch under normal and special angling regulations in the North Branch of the Au Sable River, Michigan. (Alexander and Ryckman 1976)
Trends in angling and trout populations in the Main Au Sable and North Branch Au Sable Rivers from 1959-1976. (Alexander et al. 1979)
Mathematical description of trout stream fisheries. (Clark et al. 1979)
Population dynamics of trout in some streams of the Northern Lower Peninsula of Michigan. (Gowing and Alexander 1980)
Analysis of "quality fishing" regulations through mathematical simulation of a brown trout fishery. (Clark 1981)
Effects of a slotted size limit on the brown trout fishery of the Au Sable River, Michigan. (Clark and Alexander 1984)
Effects of a slotted size limit on a multi species trout fishery. (Clark and Alexander 1985)
Growth, survival, and vulnerability to angling of three wild brook trout strains exposed to different levels of angler exploitation over time. (Nuhfer and Alexander 1991)
Evaluation of catch-and release trout fishing regulations on the South Branch of the Au Sable River, Michigan. (Clark and Alexander 1992)
Comparative catchability, growth, and survival of two wild stocks of brown trout. (Alexander and Nuhfer 1993)
Recruitment of brown trout in the South Branch of the Au Sable River, Michigan in relation to stream flow and winter severity. (Nuhfer et al. 1994)
Predator-prey relations
Trout populations and predator studies, North Branch Au Sable, 1960-62. (Alexander and Shetter 1962)
Progress report on brown trout removal from 4.2 miles of the North Branch of the Au Sable River, 1964 and 1965. (Shetter and Alexander 1966)
Diet of vertebrate predators on trout waters in north central Lower Michigan. (Alexander 1976)
Consumption of small trout by large predatory brown trout in the North Branch of the Au Sable River, Michigan. (Alexander 1977)

Table 18.–Continued.

Behavior and movement
Observations on movements of wild trout in two Michigan stream drainages. (Shetter 1967)
Movement, habitat use, and daily activity patterns of trophy brown trout in the South Branch of the Au Sable River, Michigan. (Clapp 1988)
Range of movement and daily activity of wild brown trout in the South Branch Au Sable River, Michigan. (Regal 1992)
Seasonal and daily movements of large brown trout in the Mainstem Au Sable River, Michigan. (Hudson 1993)
Diet and growth
Relationships between diet and growth in rainbow trout (*Salmo gairdneri)*, brook trout *(Salvelinus fontinalis)*, and brown trout *(salmo trutta)*. (Alexander and Gowing 1976)
A comparison of the diet and growth of trout from the upper Au Sable and upper Manistee rivers, Michigan. (Strogen 1979)
Growth rate of brown trout (Salmo trutta) in areas of the Au Sable River, Michigan, before and after domestic sewage diversion. (Merron 1982)
Comparative growth and survival potential of brown trout from four wild stocks and one domestic stock. (Alexander 1985)
A comparison of growth of brown trout from selected western rivers with growth of brown trout from Michigan rivers. (Nuhfer 1988)

Table 19.–Fish community data from 1990 electrofishing surveys conducted at six riverine sites above (A-) and below (B-) Consumers Energy ponds on the Au Sable River. Blanks indicate zero's. Data from Lawler, Matusky, and Skelly Engineers (1991a-c, f).

	Catch by number						Catch by weight (kg)					
Species	A-Mio	B-Mio	A-Alcona	B-Alcona	A-Loud	B-Foote	A-Mio	B-Mio	A-Alcona	B-Alcona	A-Loud	B-Foote
Coldwater riverine fishes												
American brook lamprey				1						0.26		
Blacknose dace	419	29	364	4	1		4.76	0.07	0.53	0.04	0.01	
Brook trout	22	1					1.98	0.04				
Brown trout	41	23	2		5	3	9.07	3.18	1.05		0.58	0.29
Longnose dace	38	69	215	2	5		0.29	0.18	1.07	0.01	0.02	
Mottled sculpin	36	1	42				0.30	0.01	0.18			
Rainbow trout	8	1				24	0.92	0.27				5.60
Salmonid parr						173						0.35
Steelhead						24						21.09
Whitefish spp.	25						11.50					
TOTALS	589	124	623	7	11	224	28.83	3.75	2.83	0.05	0.61	27.32
TOTALS PER PASS	147	41	208	2	4	37	7.21	1.25	0.94	0.01	0.20	4.55
Coolwater riverine and lentic fishes												
Northern pike					1						0.30	
Walleye		5		2	4	17		1.14		1.77	1.11	18.12
Yellow perch				2	2	6				0.06	0.08	0.30
Brassy minnow						1						<0.01
Catostomidae	4	106	153	70		5	0.01	0.23	0.55	0.46		18.07
Creek chub	126	179	307	12	3		1.69	1.98	10.37	0.05	0.05	
Golden redhorse				5		7				7.05		3.30
Greater redhorse		27	3	3	4			70.21	2.06	6.74	8.40	
Hornyhead chub						17						0.15
Logperch		20	177	18	118			0.20	3.79	0.17	0.82	
Longnose sucker						86						74.82
Northern hog sucker	15	192	27	57	65	22	1.43	107.41	11.37	10.39	10.92	0.47
Petromyzontidae	38	37	222	18	48	19	0.20	0.10	0.92	0.06	0.10	0.28
Rainbow darter	2	36	23		76		0.00	0.09	0.05		0.16	

Table 19.–Continued.

Species	Catch by number						Catch by weight (kg)					
	A-Mio	B-Mio	A-Alcona	B-Alcona	A-Loud	B-Foote	A-Mio	B-Mio	A-Alcona	B-Alcona	A-Loud	B-Foote
Coolwater riverine & lentic fishes continued												
River chub		5			55			0.02			1.29	
Rock bass	3	12	4	30	12	12	0.12	0.15	0.01	0.79	0.24	1.54
Sand shiner						392						0.98
Shorthead redhorse				7						11.84		
Smallmouth bass		32	2	59	36	23		0.13	0.01	1.42	0.59	8.91
Stonecat		8	5	2	16	1		0.14	0.33	0.05	0.61	0.02
White sucker	104	242	19	253	20	176	25.92	141.69	7.23	6.51	13.66	151.66
Blackchin shiner	1						0.00					
TOTALS	293	901	942	538	460	784	29.37	323.51	36.68	47.38	38.32	278.62
TOTALS PER PASS	73	300	314	135	153	131	7.34	107.84	12.23	11.84	12.77	46.44
Warmwater lentic fishes												
Black crappie		1						<0.01				
Blackside darter	60	66	67	8	124		0.45	0.88	0.23	0.07	0.72	
Bluntnose minnow			22			3			0.08			0.01
Brook stickleback						3						0.01
Emerald shiner						14						0.04
Gizzard shad						1						0.95
Golden shiner	1					1	<0.01					0.01
Johnny darter	13	82	91	4	9	28	0.04	0.15	0.14	0.01	0.02	0.07
Largemouth bass		1	3		1	3		<0.01	0.02		<0.01	1.27
Lepomis spp.				2						0.03		
N. redbelly dace	8						0.02					
Spotfin shiner						1						0.01
Spottail shiner	2			86	10	1	0.01			0.13	0.03	<0.01
Stickleback		1	2					<0.01	<0.01			
Common shiner	52	98	74	21	2	2	0.57	0.21	0.10	0.62	0.02	0.06
Blacknose shiner	3						0.01					

Table 19.–Continued.

Species	Catch by number						Catch by weight (kg)					
	A-Mio	B-Mio	A-Alcona	B-Alcona	A-Loud	B-Foote	A-Mio	B-Mio	A-Alcona	B-Alcona	A-Loud	B-Foote
TOTALS	139	249	259	121	146	57	1.10	1.23	0.58	0.86	0.78	2.42
TOTALS PER PASS	35	83	86	30	49	10	0.27	0.41	0.19	0.22	0.26	0.40
TOTAL PER PASS	255	425	608	167	206	178	14.82	109.50	13.36	12.07	13.24	51.39
# OF SPECIES	22	25	21	22	22	28						
Percent of total catch by number or weight												
Coldwater	58	10	34	1	2	21	49	1	7	0	2	9
Coolwater	29	71	52	81	75	74	50	98	91	98	96	90
Warmwater	14	20	14	18	24	5	2	0	1	2	2	1
Number of passes	4	3	3	4	3	6						
Area sampled (acres)	3.7	4.0	3.0	3.2	3.5	3.3						

Table 20.–Total catch of fishes by number and weight from netting surveys conducted at Consumers Energy ponds on the Au Sable River. Data are a combination of trap net, fyke net, and gill net surveys. Data from United States Forest Service – Michigan Department of Natural Resources Fisheries Division pond surveys conducted during the following years: Mio- 1996; Alcona- 1995; Loud- 1996; Five Channels- 1997; Cooke –1994; and Foote- 1996. Blanks indicate zeros.

	Mio		Alcona		Loud		Five Channels		Cooke		Foote	
Species	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
Black bullhead	18	4.4										
Black crappie	13	9.1	15	15.9	3	3.9	9	10.5	24	13.5	19	12.4
Bluegill	13	2.1	4	2.3	117	25.9	9	1.4	11	2.5	49	2.8
Bowfin	73	442.3	12	66.8	56	343.5	16	67.3	34	166.5	77	372.6
Brown bullhead	54	34.4	32	42.5	167	140.9	2	2.6	221	244.0	276	227.8
Brown trout	2	4.2										
Carp	1	14.2			2	22.3			39	391.9	7	131.4
Channel catfish											1	17.1
Creek chub			3	0.0					2	0.0		
Fathead minnow			1	0.0								
Golden shiner			4	0.0	1	0	1	0.1	10	0.5		
Golden redhorse					62	311.7	5	20.9				
Greater redhorse					14	71.5						
Green sunfish					6	0.6						
Largemouth bass	5	16.8			8	17.9	1	1.8	9	19.2	2	5.8
Northern pike	78	203.5	14	34.3	20	40.5	23	62.2	25	38.4	100	198.5
Pumpkinseed	38	2.5	3	1.0	268	48.7	10	2.3	40	12.7	169	31.0
Rock bass	41	6.3	154	43.4	219	49.6	79	24	192	50.8	556	182.7
Round whitefish	3	4.9										
Sand shiner			7	0.0								
Silver redhorse							18	63.5				
Smallmouth bass	9	19.1	39	48.5	2	4.8	6	13.4	14	12.5	65	103.2
Unidentified redhorse					22	98.4	15	47.7	1	4.5		
Walleye	13	45.1	10	27.1	3	11.8	5	6.6	16	38.0	10	29.3
White sucker	117	289.1	79	171.9	66	195.9	8	22.3	5	14.5	5	23.9
Yellow bullhead	13	12.2	7	7.5	80	54.4					34	34.3
Yellow perch	108	9.9	18	9.7	49	10.9	20	5.3	9	0.9	38	4.3
TOTALS	599	1120.1	402	470.9	1165	1453.2	227	351.9	652	1011.1	1408	1377.1

Table 20.–Continued.

Species	Mio		Alcona		Loud		Five Channels		Cooke		Foote	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds
% bowfin + bullhead	26	44	13	25	26	37	8	20	39	41	27	46
% suckers	20	26	20	37	14	47	20	44	1	2	0	2
% bass, pike, + walleye	18	25	16	23	3	5	15	24	10	11	13	24
% sunfish	18	2	44	13	53	9	47	11	41	8	56	17

Table 21.–Amphibian and reptile species found in counties of the Au Sable River watershed. Data from Harding and Holman (1992), Holman et al. (1989), and Harding and Holman (1990). Threatened (T) and special concern (SC) species are noted in bold. Ot = Otsego, C = Crawford, Os = Oscoda, M = Montmorency, Og = Ogemaw, R = Roscommon, A = Alcona, I = Iosco.

Common name	Scientific name	Ot	C	Os	M	Og	R	A	I
Frogs and toads									
Western chorus frog	*Pseudacris triseriata triseriata*	X	X	X	X	X	X	X	X
Northern spring peeper	*Pseudacris crucifer crucifer*	X	X	X	X	X	X	X	X
Eastern gray tree frog	*Hyla versicolor*	X	X	X	X	X	X	X	X
Cope’s gray tree frog	*Hyla chrysoscelis*	X	X	X	X	X	X	X	X
Green frog	*Rana clamitans melanota*	X	X	X	X	X	X	X	X
Bull frog	*Rana catesbeiana*	X	X	X	X	X	X	X	X
Northern leopard frog	*Rana pipiens*	X	X	X	X	X	X	X	X
Pickerel frog	*Rana palustris*	X	X	X	X	X	X	X	X
Wood frog	*Rana sylvatica*	X	X	X	X	X	X	X	X
Eastern American toad	*Bufo americanus americanus*	X	X	X	X	X	X	X	X
Salamanders									
Blue-spotted salamander	*Ambystoma laterale*	X	X	X	X	X	X	X	X
Spotted salamander	*Ambystoma maculatum*	X	X	X	X	X	X	X	X
Eastern tiger salamander	*Ambystoma tigrinum tigrinum*	X	X	X	X	X	X		
Eastern newt- central subspecies	*Notophthalmus viridescens louisianensis*	X	X	X	X	X	X	X	X
Red-backed salamander	*Plethodon cinereus*	X	X	X	X	X	X	X	X
Four-toed salamander	*Hemidactylium scutatum*	X	X	X	X	X	X	X	X
Mudpuppy	*Necturus maculosus maculosus*	X	X	X	X	X	X	X	X
Snakes and lizards									
Northern water snake	*Nerodia sipedon sipedon*	X	X	X	X	X	X	X	X
Brown snake	*Storeria dekayi*	X	X	X	X	X	X	X	X
Northern red-bellied snake	*Storeria occipitomaculate occipitomaculate*	X	X	X	X	X	X	X	X
Eastern garter snake	*Thamnophis sirtalis sirtalis*	X	X	X	X	X	X	X	X
Butler’s garter snake	*Thamnophis butleri*			X		X		X	X
Northern ribbon snake	*Thamnophis sauritus septentrionalis*	X	X	X	X	X	X	X	X
Northern ringneck snake	*Diadophis punctatus edwardsi*	X	X	X	X	X	X	X	X
Eastern hognose snake	*Heterodon platyrhinos*	X	X	X	X	X	X	X	X
Eastern milk snake	*Lampropeltis triangulum triangulum*	X	X	X	X	X	X	X	X
Eastern smooth green snake	*Opheodrys vernalis vernalis*	X	X	X	X	X	X	X	X
Eastern massasauga rattlesnake (SC)	***Sistrurus catenatus catenatus***	X	X	X	X	X	X	X	X
Five-lined skink	*Eumeces fasciatus*	X	X	X	X	X	X	X	X
Turtles									
Snapping turtle	*Chelydra serpentina*	X	X	X	X	X	X	X	X
Wood turtle (T)	***Clemmys insculpta***	X	X	X	X	X	X	X	X
Blandings turtle (SC)	***Emydoidea blandingii***	X	X	X	X	X	X	X	X
Common map turtle	*Graptemys geographica*						X		
Painted turtle	*Chrysemys picta*	X	X	X	X	X	X	X	X
Spiny softshell turtle	*Apalone spinifera*		X				X		

Table 22.–Birds associated with aquatic and wetland habitats in the Au Sable River watershed. State-threatened species are in bold. Data from T. Filippi (USFS, Mio, personal communication).

Common Name	Scientific Name
Double-crested cormorant	*Phalacrocorax auritus*
Great blue heron	*Ardea herodias*
Black-crowned night heron	*Nyticorax nyticorax*
Canada goose	*Branta canadensis*
Wood duck	*Aix sponsa*
American black duck	*Anas rubripes*
Mallard	*Anas platyrhynchos*
Ring-necked duck	*Athya collaris*
Common goldeneye	*Bucephala clangula*
Hooded merganser	*Lophodytes cucullatus*
Common merganser	*Mergus merganser*
Osprey	***Pandion haliaetus***
Bald eagle	***Haliaeetus leucocephalus***
Red-shouldered hawk	***Buteo lineatus***
Spotted sandpiper	*Actitis macularia*
Ring-billed gull	*Larus delawarensis*
Herring gull	*Larus argentatus*
Common tern	*Sterna hirundo*
Belted kingfisher	*Ceryle alcyon*
Rough-winged swallow	*Stelgidopteryx serripennis*
Bank swallow	*Riparia riparia*
Common loon	***Gavia immer***
Pied-billed grebe	*Podilymbus podiceps*
American bittern	*Botaurus lentiginosus*
Least bittern	*Ixobrychus exilis*
Green heron	*Butorides striatus*
Trumpeter swan	*Cygnus buccinator*
Blue-winged teal	*Anas discors*
Northern pintail	*Anas acuta*
Red-breasted merganser	*Mergus serrator*
Virginia rail	*Rallus limicola*
Sora	*Porzana carolina*
Common gallinule	*Gallinula chloropus*
American coot	*Fulica americana*
Sandhill crane	*Grus canadensis*
Common snipe	*Gallinago gallinago*
Black tern	*Chlidonias niger*
Barred owl	*Strix varia*
Olive-sided flycatcher	*Contopus borealis*
Alder flycatcher	*Empidonax alnorum*
Willow flycatcher	*Empidonax traillii*
Eastern phoebe	*Sayornis phoebe*
Tree swallow	*Tachycineta bicolor*
Sedge wren	*Cistothorus platensis*
Marsh wren	*Cistothorus palustris*

Table 22.–Continued.

Common Name	Scientific Name
Yellow-warbler	*Dendroica petechia*
Prothonotary warbler	*Protonotaria citrea*
Northern waterthursh	*Seiurus noveboracensis*
Connecticut warbler	*Oporornis formosus*
Common yellowthroat	*Geothlypis trichas*
Wilson's warbler	*Wilsonia pusilla*
Swamp sparrow	*Melospiza georgiana*
Red-winged blackbird	*Agelaius phoeniceus*

Table 23.–Mammals in the Au Sable River watershed from Kurta (1995). Threatened and special concern species are noted and in bold.

Common Name	Scientific Name
Virginia opossum	*Didelphis virginiana*
Masked shrew	*Sorex cinereus*
Pygmy shrew	*Sorex hoyi*
Water shrew	*Sorex palustris*
Northern short-tailed shrew	*Blarina brevicauda*
Eastern mole	*Scalopus aquaticus*
Star-nosed mole	*Condylura cristata*
Little brown bat	*Myotis lucifugus*
Northern bat	*Myotis septentrionalis*
Red bat	*Lasiurus borealis*
Hoary bat	*Lasiurus cinereus*
Silver-haired bat	*Lasionycteris noctivagans*
Big brown bat	*Eptesicus fuscus*
Eastern cottontail	*Sylvilagus floridanus*
Snowshoe hare	*Lepus americanus*
Eastern chipmunk	*Tamias striatus*
Woodchuck	*Marmota monax*
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*
Eastern gray squirrel	*Sciurus carolinensis*
Eastern fox squirrel	*Sciurus niger*
Red squirrel	*Tamiasciurus hudsonicus*
Northern flying squirrel	*Glaucomys sabrinus*
Southern flying squirrel	*Glaucomys volans*
American beaver	*Castor canadensis*
White-footed mouse	*Peromyscus leucopus*
Deer mouse	*Peromyscus maniculatus*
Southern red-backed vole	*Clethrionomys gapperi*
Meadow vole	*Microtus pennsylvanicus*
Woodland vole (special concern)	***Microtus pinetorum***
Muskrat	*Ondatra zibethicus*
Southern bog lemming	*Synaptomys cooperi*
House mouse	*Mus musculus*
Norway rat	*Rattus norvegicus*
Woodland jumping mouse	*Napaeozapus insignis*
Meadow jumping mouse	*Zapus hudsonius*
Common porcupine	*Erethizon dorsatum*
Coyote	*Canis latrans*
Red fox	*Vulpes vulpes*
Common gray fox	*Urocyon cinereoargenteus*
Black bear	*Ursus americanus*
Common raccoon	*Procyon lotor*
American marten (threatened)	***Martes americana***
Ermine	*Mustela erminea*
Long-tailed weasel	*Mustela frenata*
Least weasel	*Mustela nivalis*

Table 23.–Continued.

Common Name	Scientific Name
Mink	*Mustela vison*
American badger	*Taxidea taxus*
Striped skunk	*Mephitis mephitis*
Northern river otter	*Lutra canadensis*
Bobcat	*Lynx rufus*
Elk	*Cervus elaphus*
White-tailed deer	*Odocoileus virginianus*

Table 24.–Natural features in the Au Sable River watershed by county of occurrence. Status codes: E = endangered; T = threatened; TNL = threatened in parts of its range, not listed elsewhere; SC = Special Concern (rare, may become E or T in future). Blanks occur when none of the status categories apply. County codes: A = Alcona; C = Crawford; I = Iosco; M = Montmorency; Og = Ogemaw; Os = Oscoda; Ot = Otsego; and R = Roscommon. Data from Michigan Department of Natural Resources, Wildlife Division, Natural Features Inventory, June 1998.

Common name	Scientific Name	State Status	Federal Status	Ot	C	Os	M	Og	R	A	I
Vertebrate											
American marten	*Martes americana*	T		X	X	X			X	X	
Woodland vole	*Microtus pinetorum*	SC			X						
Kirtland's warbler	*Dendroica kirtlandii*	E	E		X	X		X	X	X	X
Prairie warbler	*Dendroica discolor*	T				X					X
Common loon	*Gavia immer*	T		X	X	X	X	X	X	X	X
Cooper’s hawk	*Accipiter cooperii*	SC								X	
Northern goshawk	*Accipiter gentilis*	SC			X	X				X	
Bald eagle	*Haliaeetus leucocophahalus*	T	TNL	X	X	X	X		X	X	X
Osprey	*Pandion haliaetus*	T			X				X		
Red-shouldered hawk	*Buteo lineatus*	T		X		X					
Wood turtle	*Clemmys insculpta*	SC			X	X				X	X
Blanding’s turtle	*Emydoidea blandingii*	SC								X	X
Eastern massasauga	*Sistrurus catenatus catenatus*	SC			X	X				X	X
Lake sturgeon	*Acipenser fulvescens*	T									X
River darter	*Percina shumardi*	E									X
Channel darter	*Percina copelandi*	T								X	X
Invertebrate											
Spike-lipped crater	*Mesodon sayanus*	SC				X					
Lake Huron locust	*Trimerotropis huroniana*	T									X
Doll's merolonche	*Merolonche dolli*	SC		X					X		
Secretive locust	*Apalachia arcana*	SC		X	X	X			X	X	X
Red-legged spittlebug	*Prosapia ignipectus*	SC			X						
Grizzled skipper	*Pyrgus wyandot*	SC		X	X						
Blazing star borer	*Papaipema beeriana*	SC		X							
Dusted skipper	*Strytonopsis hianna*	T			X	X					
Henry's elfin	*Incisalia henrici*	SC			X	X					
Boreal brachionyncha	*Brachionyncha borealis*	SC		X	X						
Vascular Plant											
Prairie or pale agoseris	*Agoseris glauca*	T		X	X	X	X				
Rough fescue	*Festuca scabrella*	T		X	X	X	X	X	X		
Long-leaved aster	*Aster longifolius*	SC			X						
Showy coneflower	*Rudbeckia fulgida var sullivantii*	SC									X
Houghton's goldenrod	*Solidage hougntonii*	T	T		X						
Pitcher's thistle	*Cirsium pitcheri*	T	T								X
Hill's thistle	*Cirsium hillii*	SC		X	X	X	X	X	X	X	X
Fleshy stitchwort	*Stellaria crassifolia*	T			X						
Whorled pogonia	*Isotria verticillata*	T									X
Calypso or fairy-slipper	*Calypso bulbosa*	T			X						
Ram's head lady-slipper	*Cypripedium arietinum*	SC		X					X	X	
False violet	*Dalibarda repens*	T			X					X	
James’ monkey-flower	*Mimulus glabratus var jamesii*	SC		X	X						

Table 24.–Continued.

Common name	Scientific Name	State Status	Federal Status	Ot	C	Os	M	Og	R	A	I
Vascular Plant (continued)											
Lake cress	*Armoracia aquatica*	T									X
Wild rice	*Zizania aquatica var aquatica*	T									X
Pine-drops	*Pterospora andromedea*	T								X	X
Alleghany or sloe plum	*Prunus alleghaniensis var davisii*	SC		X	X	X				X	
Fir clubmoss	*Lycopodium selago*	SC				X					
	Lycopodium appressum	T			X						
Plant Community											
Bog					X						
Intermittent wetland					X						
Poor fen					X					X	
Poor conifer fen					X						
Northern fen					X						X
Northern shrub thicket				X	X						
Dry sand prairie						X					
Pine barrens				X	X						
Dry northern forest					X				X	X	
Dry-mesic northern forest					X					X	X
Mesic northern forest						X					
Hardwood-conifer swamp										X	
Poor conifer swamp										X	
Rich conifer swamp					X	X				X	
Southern floodplain forest						X					X
Other Feature											
Great blue heron rookery					X				X	X	

Table 25.–Catches of young-of-year (<8 in) walleye and walleye ≥13 in from Sern's surveys of ponds and lakes in the area of the Au Sable River watershed. Asterisk indicates that the water body was not stocked during the year of the survey. "Good" walleye lakes average about 40 YOY's per mile of shoreline shocked (J. Schneider, MDNR, Fisheries Division, personal communication).

Water body	Pond (P) or lake (L)	Year	YOY(<8") #/mi	>= 13" cpe (#/hr)
Mio	P	1993	20.7	0.9
Alcona*	P	1995	128.5	4.0
Loud*	P	1996	21.0	0.0
Cooke	P	1995	0.9	0.0
Foote	P	1993	0.8	0.0
Foote	P	1996	0.4	0.0
Tea	L	1994	204.8	8.5
Margrethe	L	1994	54.3	14.6
Margrethe	L	1992	3.8	2.9
Peach*	L	1994	0.0	27.4
Houghton	L	1994	28.7	2.7
Houghton	L	1991	42.0	5.0
Wixom-Tobacco Arm	P	1994	23.6	3.6
Cedar	L	1994	10.0	0.5
Van Etten	L	1995	142.9	0.5
Secord	P	1992	1.4	0.0
Vaughn	L	1991	0.0	0.0

Table 26.–Comparison of netting catches of walleye ≥13 in from ponds and lakes in the Au Sable River watershed area and throughout Michigan. Various types of gear were used: f = fyke net, g = gill net, and t = trap net. Data from Michigan Department of Natural Resources, Fisheries Division records and J. Schneider (Michigan Department of Natural Resources, Fisheries Division, unpublished data).

Water body	Pond (P) or lake (L)	Year	# >=13" per net night	gear type
Au Sable area				
Mio	P	1997	0.2	f
Alcona	P	1995	0.3	f,g
Loud	P	1996	0.1	f
Five Channels	P	1996	0.1	f
Cooke	P	1994	0.6	f,t
Cooke	P	1995	0.0	f,g
Foote	P	1996	0.3	f
Lake St. Helen	L	1993	0.3	f,g
Peach	L	1992	3.3	f,g
Peach	L	1994	8.9	f
Secord	P	1992	0.0	f,g
Van Etten	L	1995	0.5	f,g
Wixom-Tobacco Arm	P	1994	0.5	f,g
Other Michigan lakes				
Fife	L	1993	1.4	f
Six Mile	L	1981	0.6	f
Big Manistique	L	1965	5.8	t
Black	L	1939-56	14.0	t
Burt	L	1939-56	27.0	t
Burt	L	1947	20.4	t
Burt	L	1948	56.2	t
Crooked	L	1939-56	4.0	t
East Twin	L	1939	8.1	t
Gogebic	L	1955	35.0	t
Houghton	L	1983	4.9	t
Houghton	L	1955	8.4	t
Hubbard	L	1948	0.7	t
Hubbard	L	1947	1.4	t
Jewett	L	1975-93	6.0	t
Long	L	1948	0.3	t
Manistee	L	1973-84	1.2	t
Mullett	L	1939-56	37.0	t

Table 27.–Recreational use of portions of the mainstem, North and South branches Au Sable River. Values are rounded and represent yearly estimates or averages for several years. Summary data (in bold) are weighted averages adjusted for the length of reach studied or period of data collected. All values expressed as number per mile. Data from Alexander and Shetter (1967), Alexander et al. (1979), Clark (1982), Clark (1984), Clark (1987), Clark and Alexander (1992), and R. Clark (Michigan Department of Natural Resources Fisheries Division, unpublished data).

				Legal fish harvested or released			
Location	Year(s)	Miles	Angler hours	Brown trout	Brook trout	Brown +brook	Pleasure boating hours
North Branch Au Sable River							
Sheep Ranch to Kellogg's Bridge	1958-60	13.5	1360	120	70	190	<12
Sheep Ranch to Kellogg's Bridge	1961-67	13.5	2060	280	370	650	
Sheep Ranch to Kellogg's Bridge	1976	13.5	1790	200	170	370	
Sheep Ranch to Kellogg's Bridge	1979	13.5	1460	110	140	250	
Sheep Ranch to Kellogg's Bridge	1980	13.5	1490	240	320	560	
Sheep Ranch to Kellogg's Bridge	1981	13.5	2550	480	570	1050	
Sheep Ranch to Kellogg's Bridge	1982	13.5	1970	110	90	200	
Sheep Ranch to Kellogg's Bridge	1985	13.5	2020	160	330	490	
Sheep Ranch to Kellogg's Bridge	1986	13.5	1700	250	200	450	
Sheep Ranch to Kellogg's Bridge	1987	13.5	1560	180	210	390	
Sheep Ranch to Kellogg's Bridge	1988	13.5	1800	150	190	340	
Sheep Ranch to Kellogg's Bridge	1989	13.5	1360	150	50	200	
Sheep Ranch to Kellogg's Bridge	1990	13.5	1440	70	290	360	
Sheep Ranch to Eamon's Landing	**1958-81**	**4.8**	**2900**	**360**	**650**	**1010**	
Eamon's Landing to Kellogg's Bridge	**1958-81**	**8.7**	**1260**	**170**	**80**	**250**	
Sheep Ranch to Kellogg's Bridge	**1958-90**	**13.5**	**1790**	**210**	**250**	**460**	
Au Sable River							
Burton to Wakeley Bridge	1960-65	8.7	4940	670	50	720	6600
Burton to Wakeley Bridge	1976	8.7	3510	110	140	250	6300
Burton to Wakeley Bridge	1979	8.7	3470	810	230	1040	9900
Burton to Wakeley Bridge	1980	8.7	3720	1200	280	1480	5100
Burton to Wakeley Bridge	1981	8.7	4320	1080	300	1380	8100
Burton to Wakeley Bridge	1982	8.7	4400	740	250	990	8600
Burton to Wakeley Bridge	1983	8.7	3420	470	300	770	6600
Burton to Wakeley Bridge	1986	8.7	5000	870	240	1110	10800
Burton to Wakeley Bridge	1987	8.7	4800	810	350	1160	7400
Grayling to Burton's Landing	**1960-83**	**5.6**	**1590**	**180**	**80**	**260**	**11600**
Burton to Wakeley Bridge	**1960-83**	**8.7**	**4380**	**700**	**150**	**850**	**7000**
Grayling to Wakeley Bridge	**1960-83**	**14.3**	**3290**	**500**	**120**	**620**	**8800**
South Branch Au Sable River							
Deerheart Valley Rd. to mouth	1960-63	16.1	1460			189	1800
Chase Bridge to Smith Bridge	1981	9.4	2470	350	180	530	4700
Chase Bridge to Smith Bridge	1982	9.4	2620	310	310	620	5600
Chase Bridge to Smith Bridge	1985	9.4	2620	170	240	410	7800
Chase Bridge to Smith Bridge	1986	9.4	1480	110	150	260	7400
Chase Bridge to Smith Bridge	1987	9.4	1470	140	180	320	7300
Chase Bridge to Smith Bridge	1988	9.4	1770	50	110	160	4100
Chase Bridge to Smith Bridge	1989	9.4	2370	230	260	490	8000
Chase Bridge to Smith Bridge	1990	9.4	3470	640	510	1150	4800
Chase Bridge to Highbanks	**1981-90**	**4**	**2060**	**350**	**260**	**610**	**6200**
Highbanks to Smith Bridge	**1981-90**	**5.4**	**2450**	**180**	**230**	**410**	**6200**
Chase Bridge to Smith Bridge	**1981-90**	**9.4**	**2280**	**250**	**240**	**490**	**6200**

Table 28.–Number of canoe liveries and registered canoes and kayaks serving the Natural River designated portions of the Au Sable River. Data are sorted by county and from the 1998 County Sheriff livery inspector's report.

County	Canoe liveries	Registered canoes and kayaks		
		1987	1992	1997
Roscommon	2	174	166	195
Crawford	12	757	836	772
Oscoda	5	584	516	678
Alcona	1	?	112	162
Iosco	1	?	46	59
TOTALS	21	1515+	1676	1866

FIGURES